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(54) **MACHINE FOR PRODUCING PACKAGING CUSHIONING**

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(51) **Int. Cl.**
B31B 1/00 (2006.01)

(52) **U.S. Cl.** **493/30**; 493/34; 493/352

(58) **Field of Classification Search** 493/30, 493/34, 13–15, 352, 350, 904, 967
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,924,154	A	2/1960	Russell et al.	
3,719,357	A	3/1973	Shields	
3,910,567	A	10/1975	Songer	
4,155,545	A	5/1979	Yanagawa et al.	
4,607,252	A *	8/1986	Neri	340/515
4,721,297	A	1/1988	Katayama et al.	
4,801,134	A	1/1989	Yokoyama et al.	
4,815,669	A	3/1989	Fujii et al.	
4,842,205	A	6/1989	Araki et al.	
4,934,686	A	6/1990	Ono et al.	
4,968,291	A	11/1990	Baldacci et al.	
4,986,481	A	1/1991	Fujii et al.	
5,009,410	A	4/1991	Fujii et al.	
5,056,604	A	10/1991	Garavuso	
5,088,972	A	2/1992	Parker	
5,123,887	A *	6/1992	Shimura	493/34
5,134,013	A	7/1992	Parker	
5,145,160	A	9/1992	Nagashima et al.	
5,167,604	A *	12/1992	Ohsawa	493/23
5,173,352	A	12/1992	Parker	
5,192,068	A	3/1993	Parker et al.	
5,213,319	A	5/1993	Crowe et al.	
5,228,673	A	7/1993	Osonoe et al.	
5,362,002	A	11/1994	Tsai	
5,387,173	A	2/1995	Simmons, Jr.	
5,571,067	A *	11/1996	Ratzel	493/30
5,624,108	A	4/1997	Kubo	
5,695,184	A	12/1997	Miller et al.	
5,712,020	A	1/1998	Parker	
5,772,129	A	6/1998	Nishio et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

JP	S38-2011 B	3/1963

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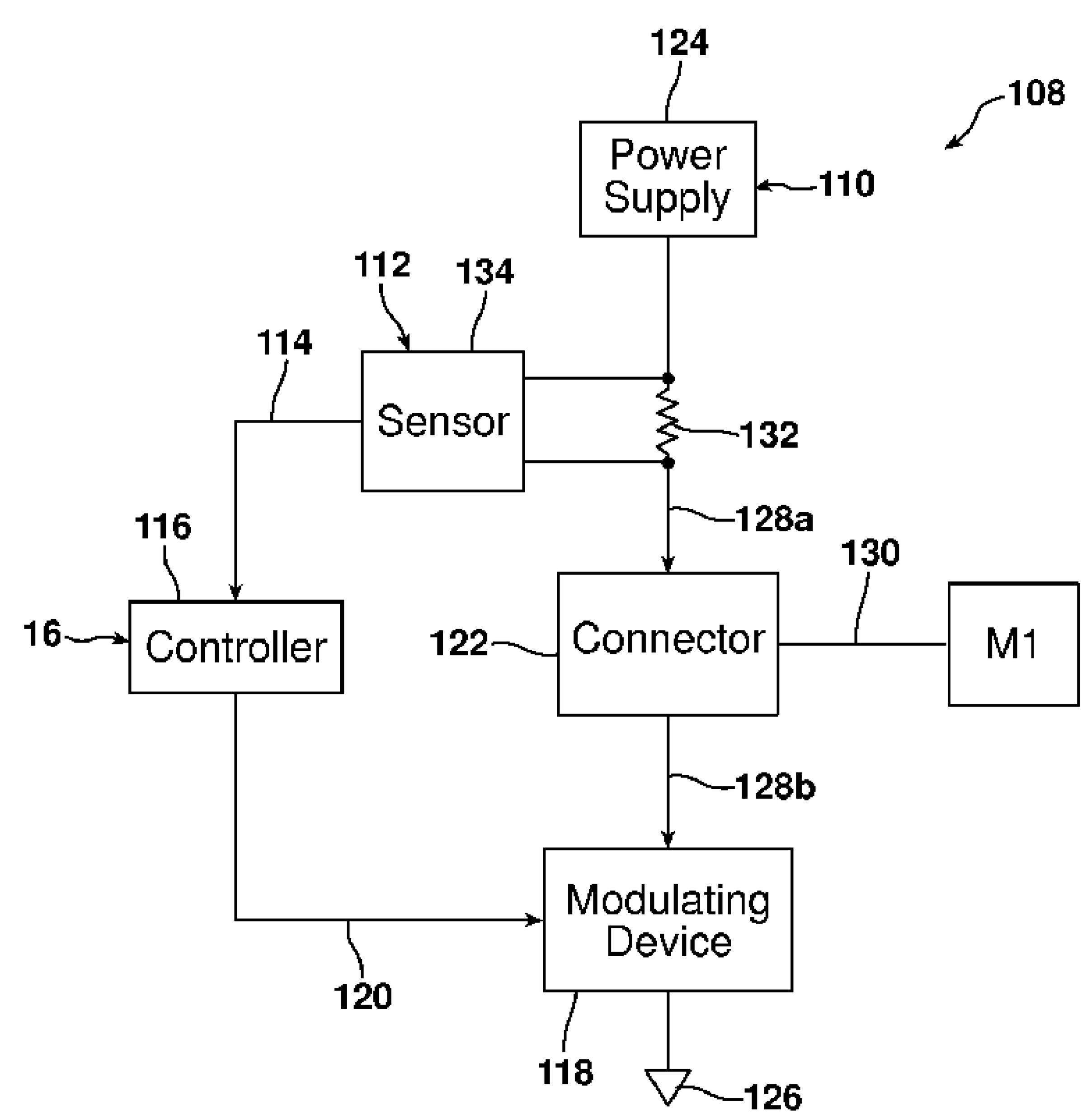
(74) *Attorney, Agent, or Firm* — Thomas C. Lagaly

(57) **ABSTRACT**

A machine for producing packaging cushioning generally includes a first feed mechanism for successively feeding sheets of a substrate at a first speed, the first feed mechanism including a motor and a power supply therefor, a second feed mechanism for receiving the sheets from the first feed mechanism and feeding the sheets at a second speed, a control unit for controlling at least one of the first and second speeds to produce a desired degree of overlap between successive sheets, and a sensor to measure the amount of electricity drawn by the motor. The control unit modulates the amount of electricity that the motor draws from a power supply when a signal from the sensor has a value that is greater than or equal to a predetermined value.

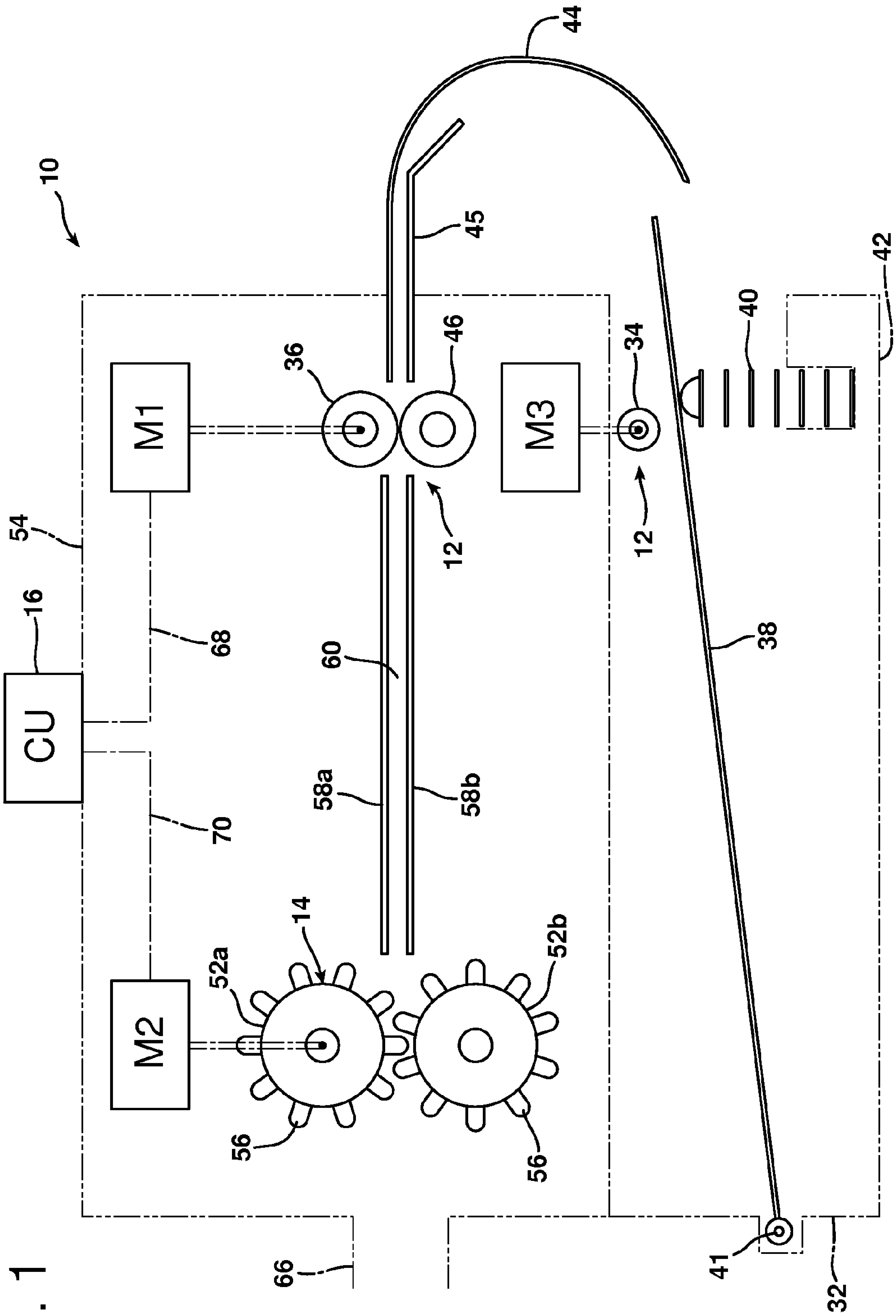
15 Claims, 14 Drawing Sheets



U.S. PATENT DOCUMENTS

5,842,694	A	12/1998	Brooks et al.
5,944,430	A	8/1999	Myung
6,017,299	A	1/2000	Ratzel
6,027,110	A	2/2000	Herrmann et al.
6,053,324	A	4/2000	Weder
6,168,847	B1	1/2001	Murphy et al.
6,189,297	B1	2/2001	Weder
6,286,827	B1	9/2001	Meetze, Jr. et al.
6,385,949	B2	5/2002	Weder
6,436,511	B1	8/2002	Ratzel
6,471,154	B1	10/2002	Toth
6,532,721	B1	3/2003	Weder
6,546,701	B2	4/2003	Weder et al.
6,610,001	B1	8/2003	Harding et al.
6,659,449	B2	12/2003	Kim
6,758,801	B2	7/2004	Harding et al.
6,918,489	B2	7/2005	Harding et al.
7,022,060	B2	4/2006	Toth
7,172,548	B2	2/2007	Toth
7,441,765	B2	10/2008	Okamoto
7,464,924	B2	12/2008	Morimoto et al.
7,490,789	B2	2/2009	Omi
7,500,664	B2	3/2009	Nakashima
2005/0082742	A1	4/2005	Kang et al.
2007/0273079	A1	11/2007	Omi et al.
2008/0153685	A1	6/2008	Cheich et al.
2009/0008871	A1	1/2009	Omi
2009/0075800	A1	3/2009	Wetsch et al.

* cited by examiner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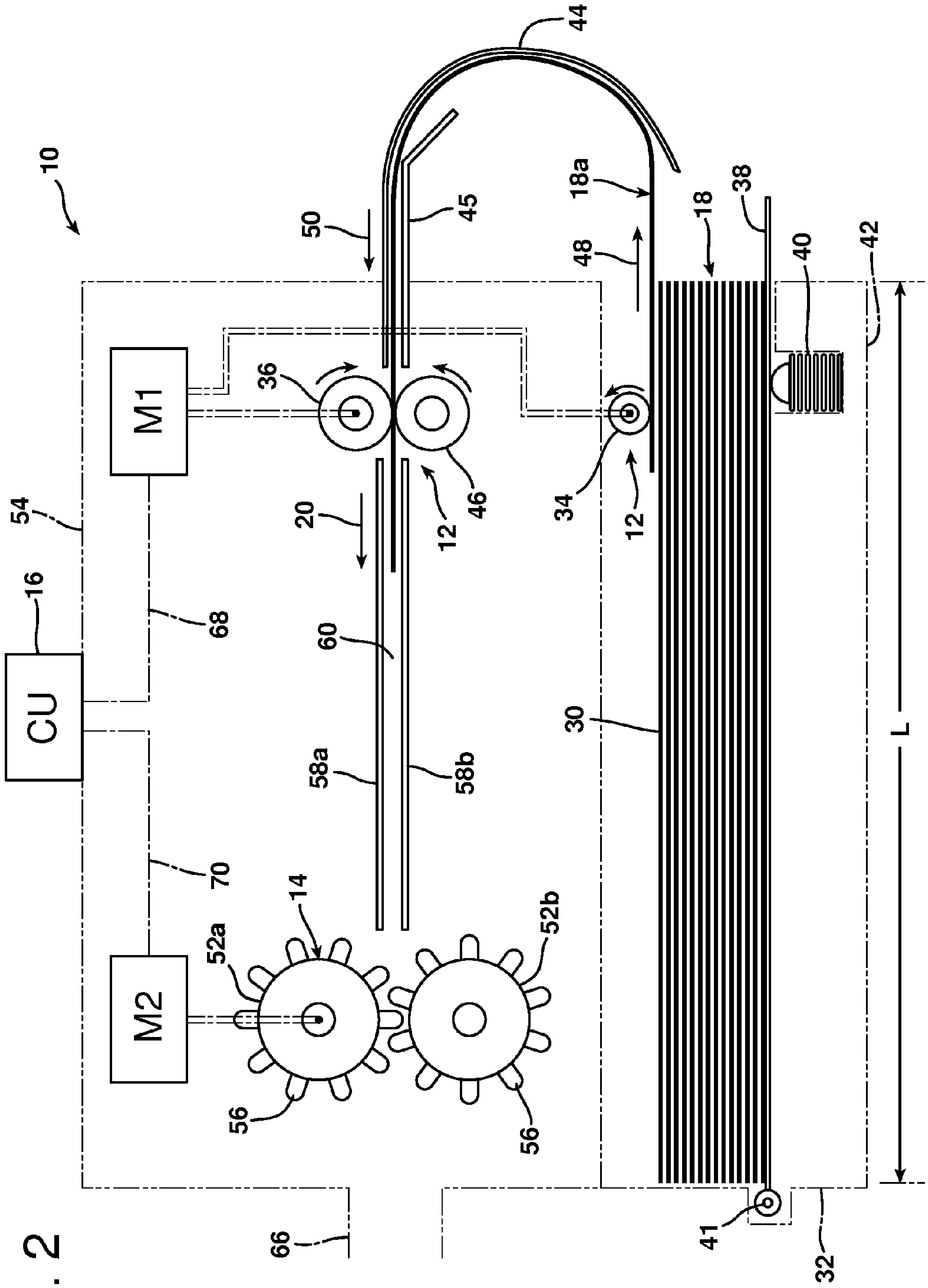
44
45
46
36
34
40
42
M1
M3
54
16
68
12
12
CU
60
38
58a
58b
70
14
52a
52b
M2
56
56
66
41
32

FIG. 1



10
44
50
45
18a
38
18
48
42
40
M1
36
34
46
12
54
20
16
68
60
CU
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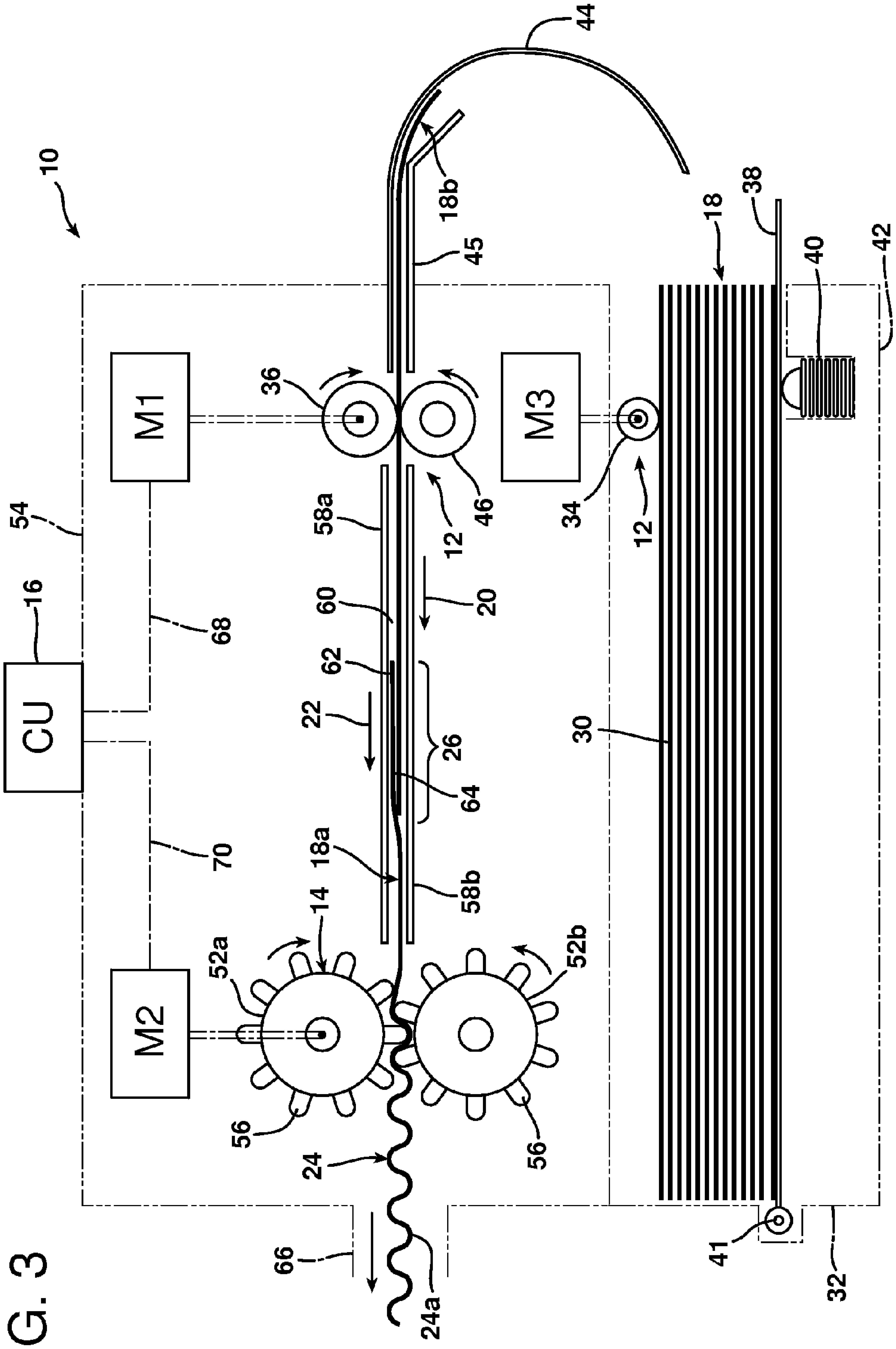
58a
58b
L
70
14
52a
52b
M2
56
41
66
32

FIG. 2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M1
M2
M3
10
12
14
16
18
18a
18b
20
22
24
24a
26
30
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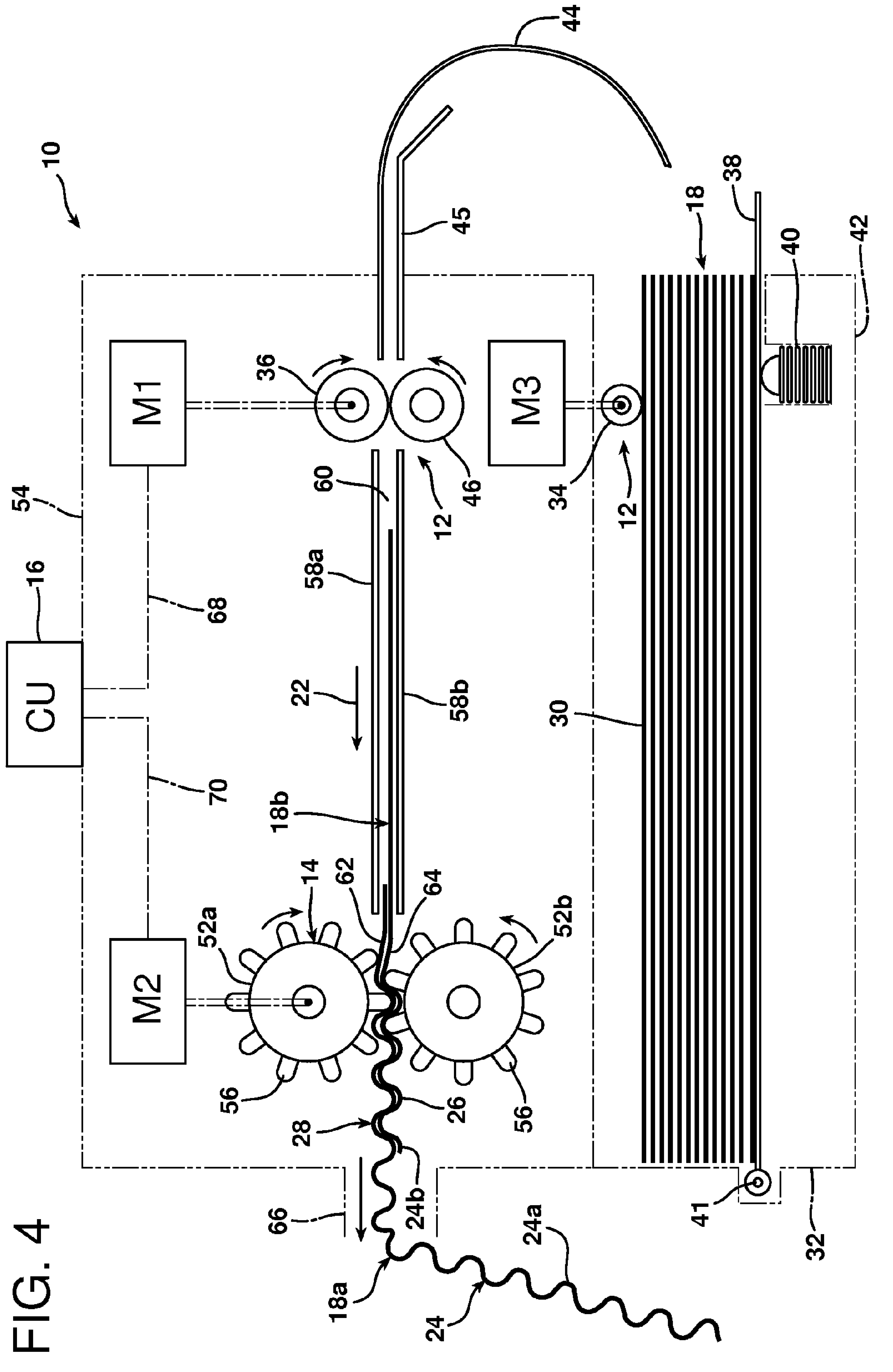
34
36
38
40
41
42
44
45
46
52a
52b
54
56
58a
58b
60
62
64
66
68
70

FIG. 3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44
45
38
18
40
42
M1
M3
36
46
12
34
12
60
54
58a
16
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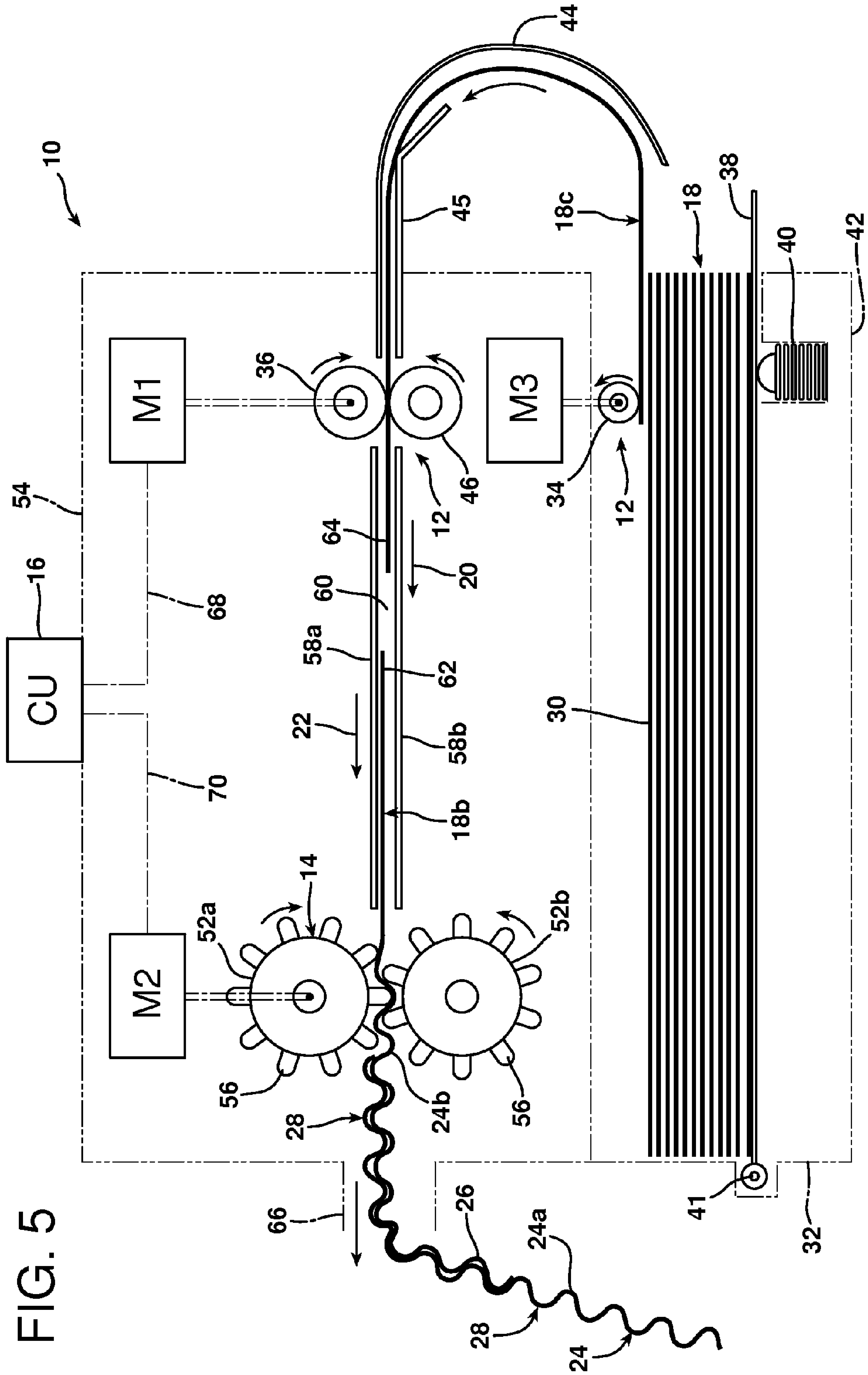
CU
22
58b
30
70
18b
14
62
64
52a
52b
M2
56
26
56
28
24b
41
66
24a
18a
24
32

FIG. 4



10
44
45
18c
18
38
40
42
54
M1
36
46
12
M3
34
12
64
60
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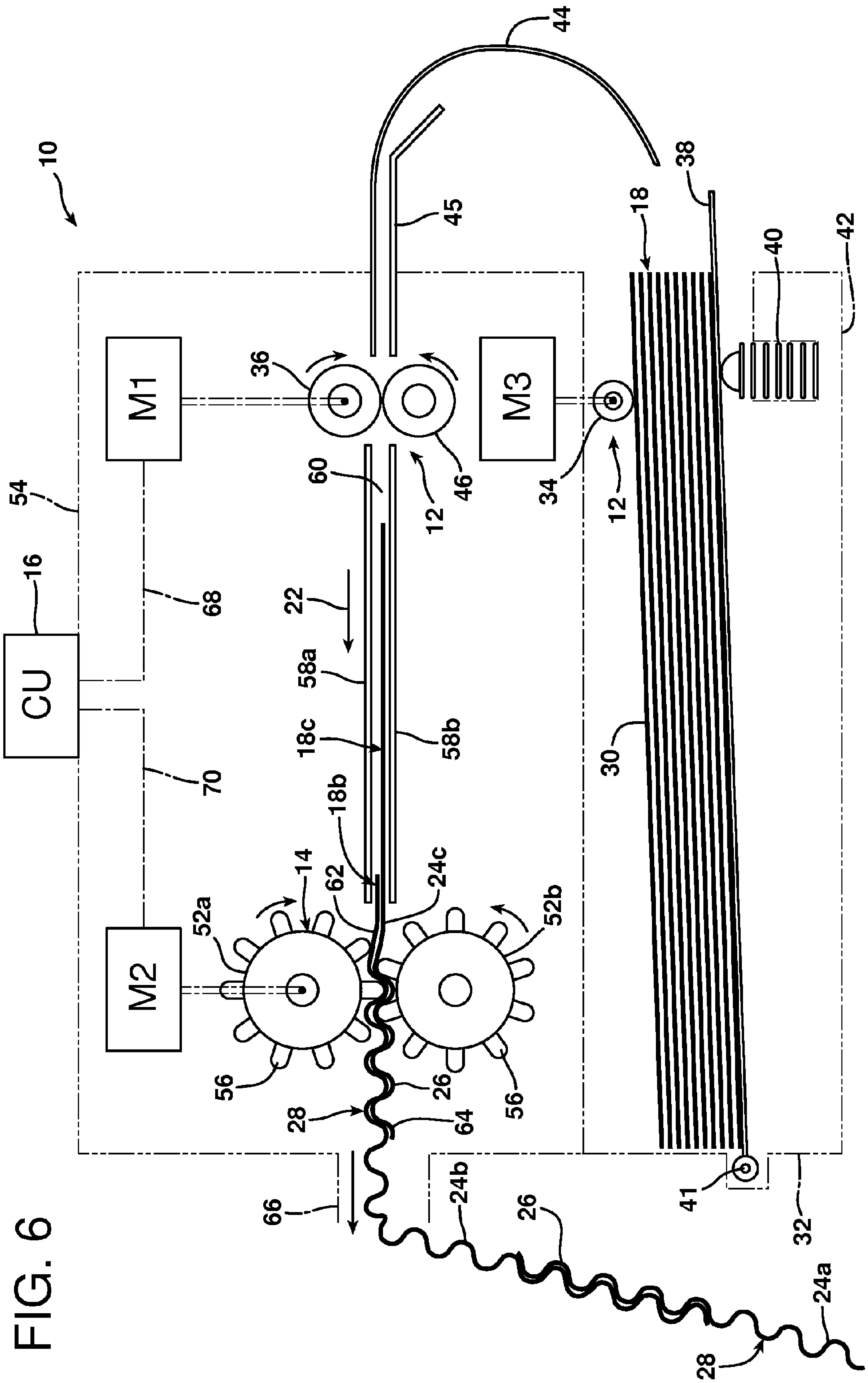
16
CU
68
58a
62
22
58b
30
70
18b
14
52a
52b
M2
56
28
24b
56
66
26
24a
41
32
28
24

FIG. 5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M3
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68
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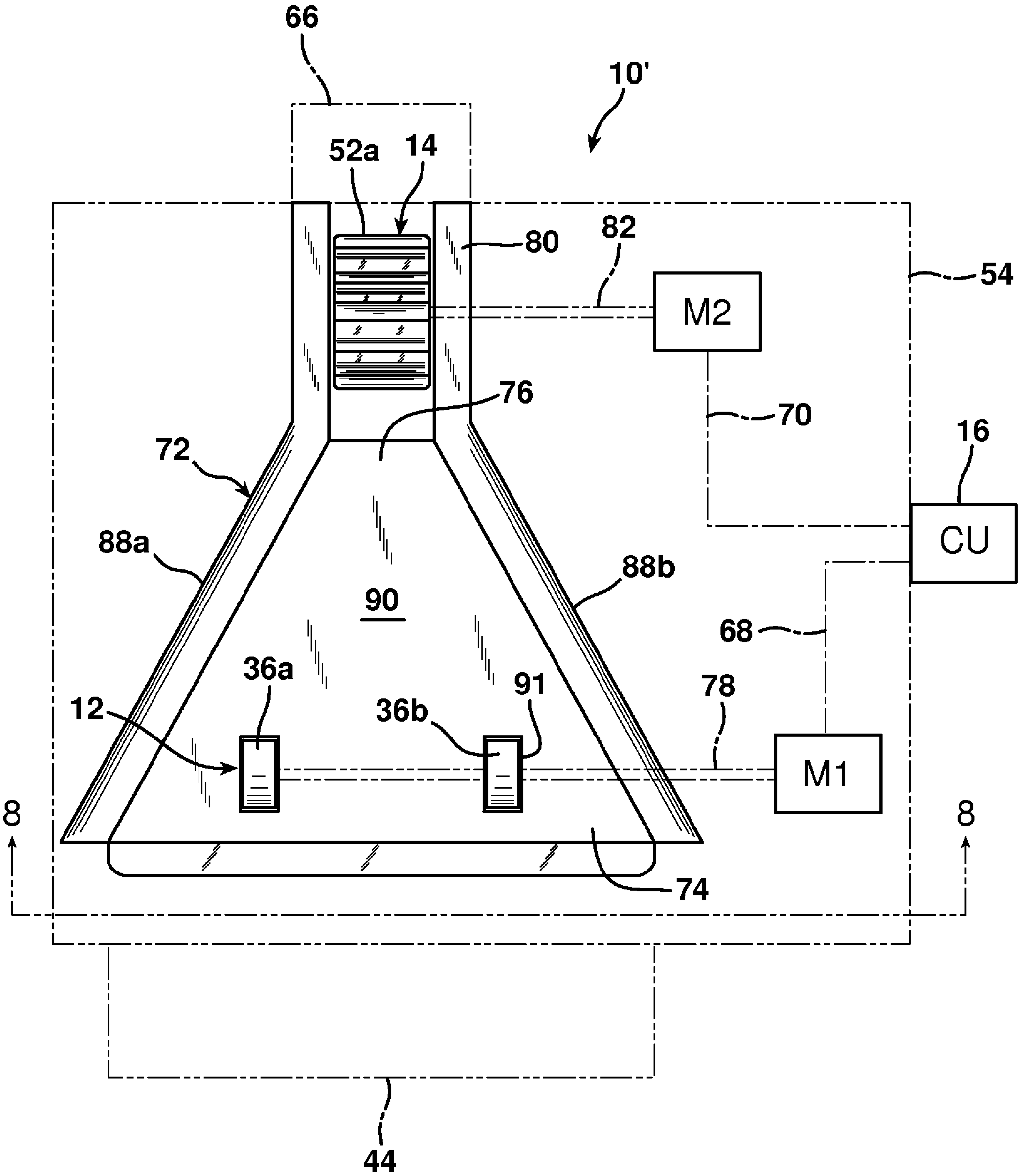
58a
18c
58b
30
70
18b
14
62
24c
52a
52b
M2
56
26
28
64
41
66
24b
24a
32

FIG. 6

FIG. 7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10'
52a
14
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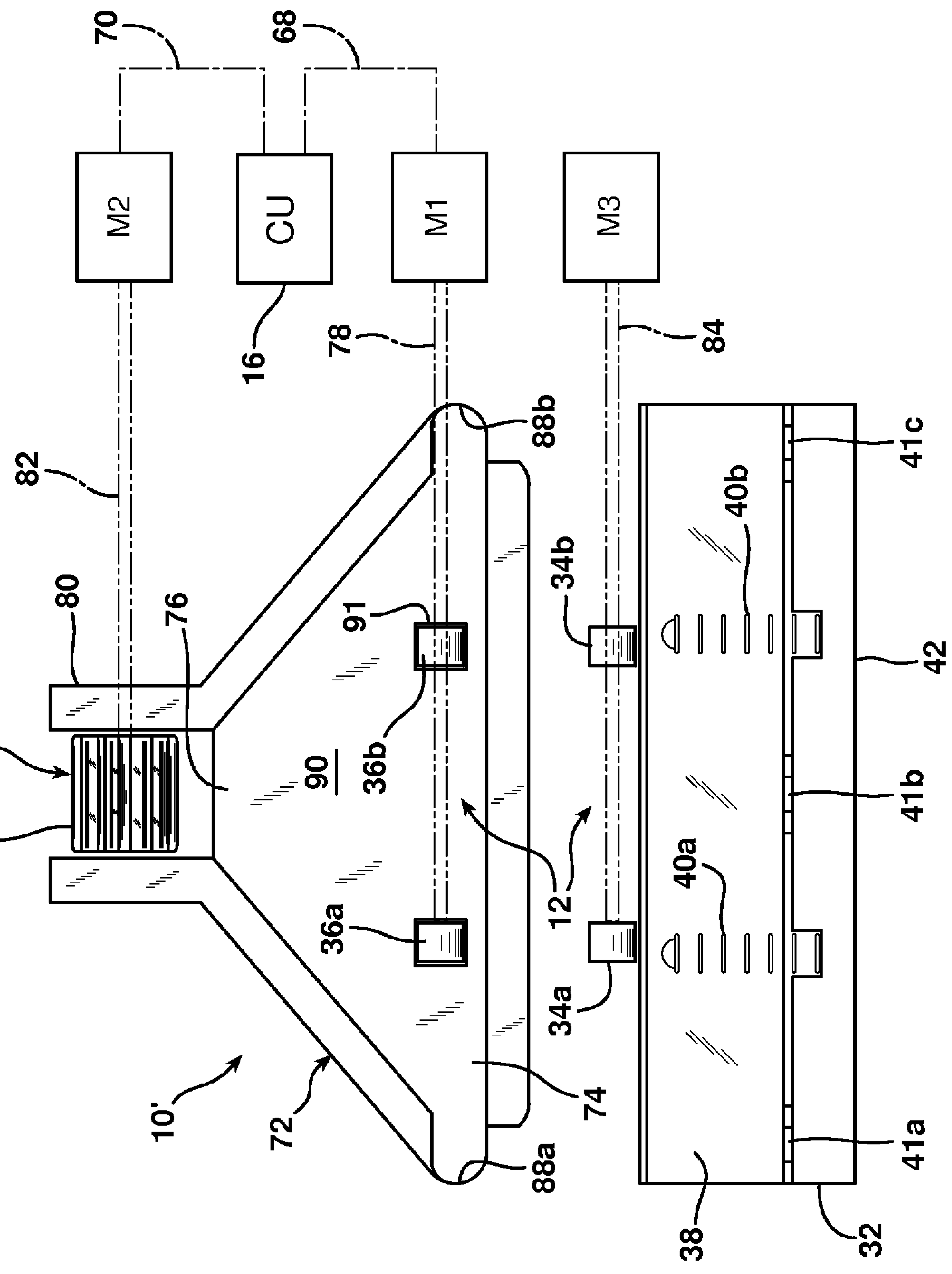
82
54
M2
76
70
16
72
CU
88a
88b
90
68
36a
91
78
12
36b
M1
8
8
74
44

FIG. 8



M2
CU
M1
M3
70
68
16
78
84
82
80
76
14
52a
91
36b
90
36a
34b
34a
88b
88a
40b
40a
41c
41b
41a
42
12
10'
72
74
38
32

FIG. 9A

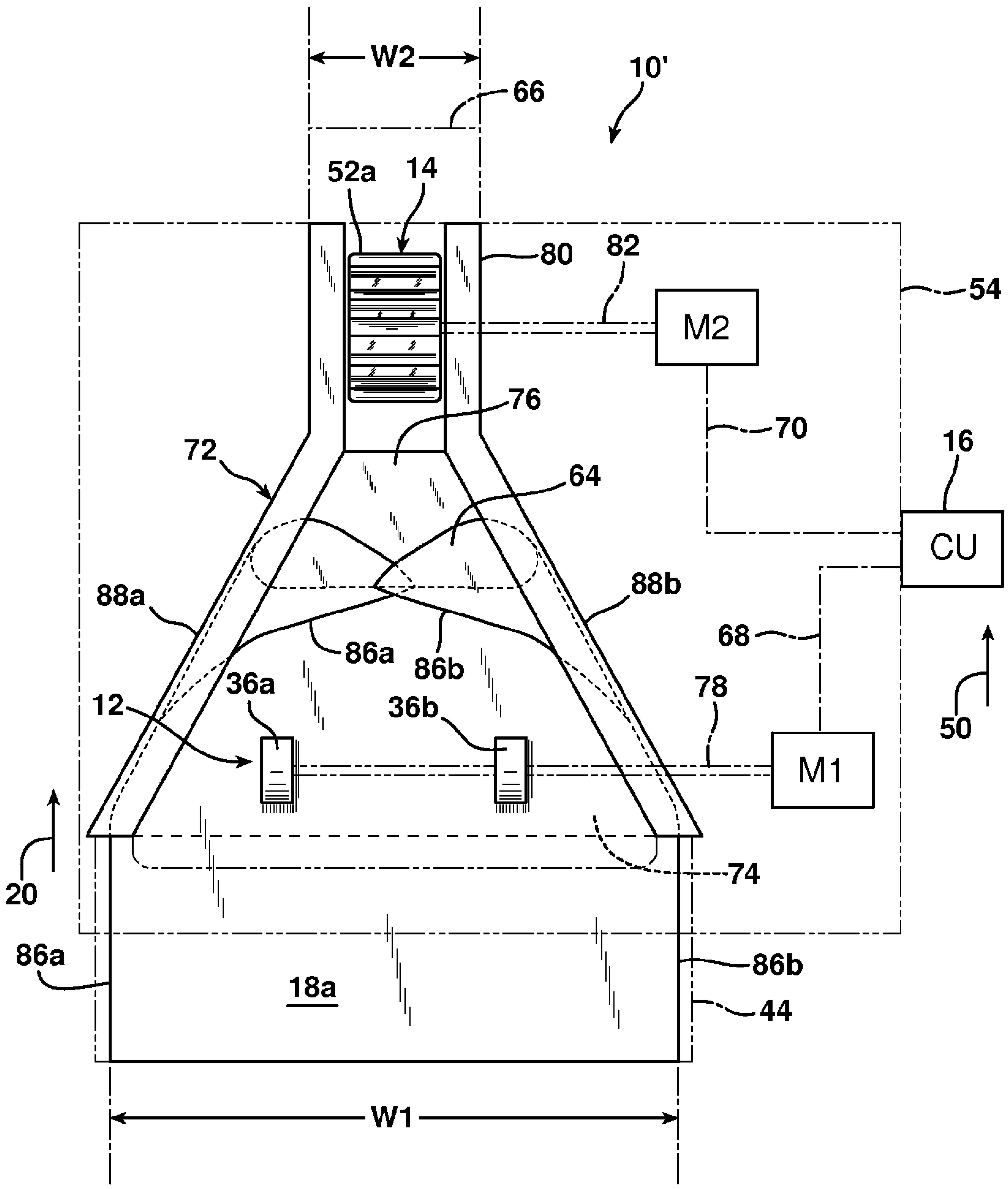
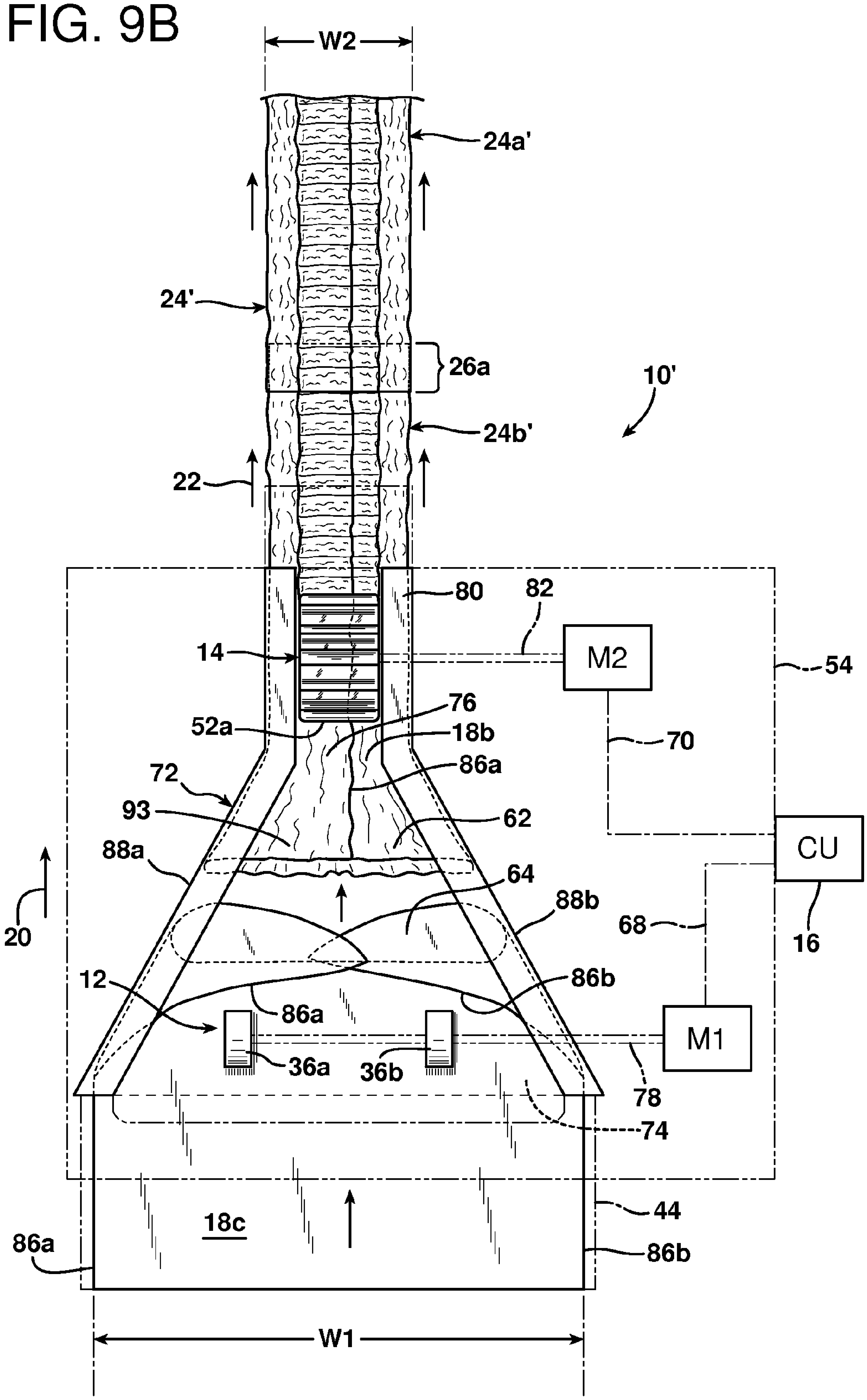

W2
10'
66
52a
14
80
82
54
M2
76
70
16
72
64
CU
88a
88b
86a
86b
68
12
36a
36b
78
50
M1
20
74
86a
18a
86b
44
W1

FIG. 9B



W2
24a'
24'
26a
10'
24b'
22
80
82
M2
14
54
76
52a
18b
70
86a
72
93
62
CU
88a
64
88b
20
68
16
12
86b
86a
M1
36a
36b
78
74
44
18c
86a
86b
W1

FIG. 10

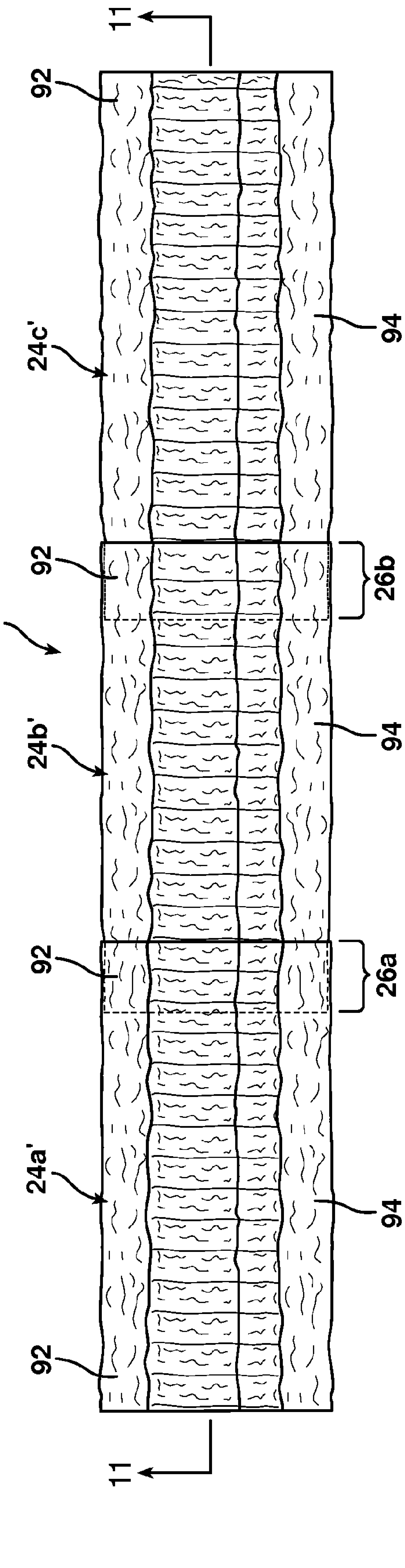


FIG. 11

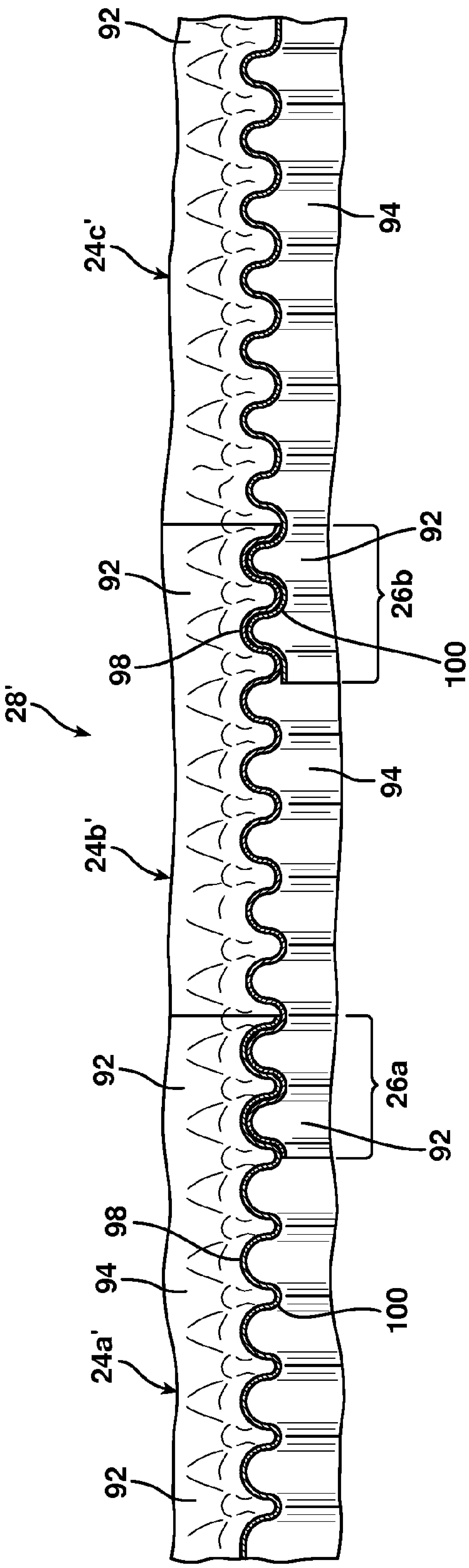


FIG. 12

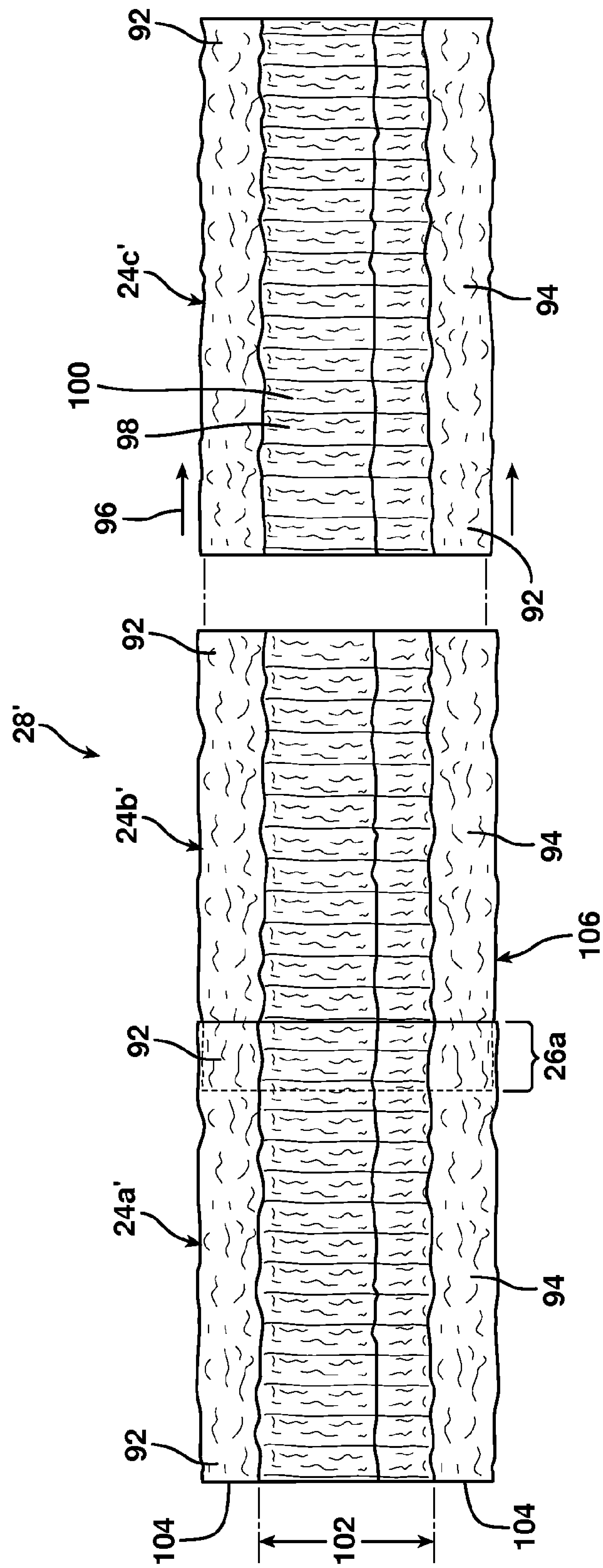
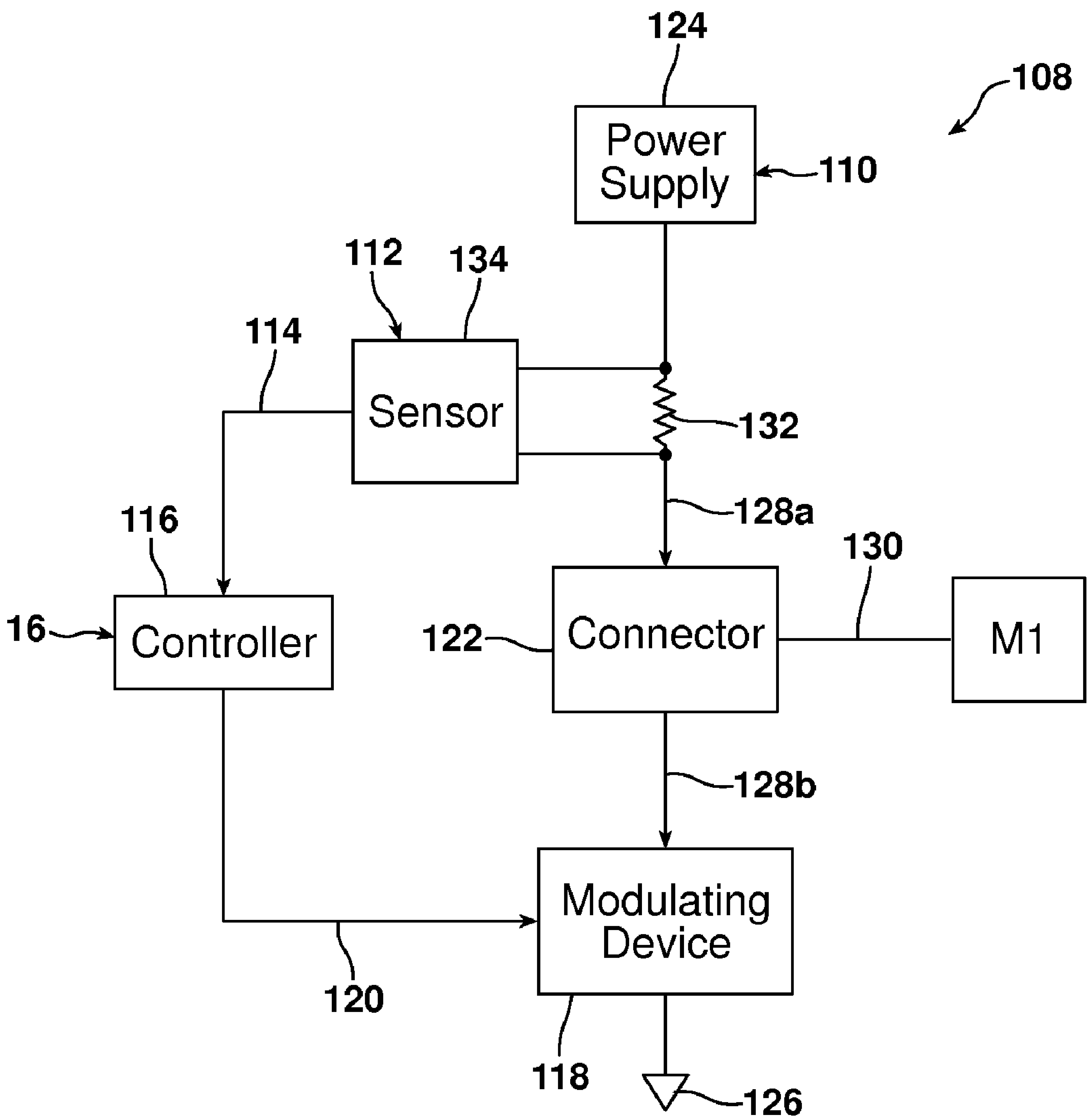


FIG. 13


124
108
Power Supply
110
112
134
114
Sensor
132
128a
116
130
16
Controller
122
Connector
M1
128b
Modulating Device
120
118
126

MACHINE FOR PRODUCING PACKAGING CUSHIONING

BACKGROUND OF THE INVENTION

The present invention relates generally to packaging materials and, more specifically, to a machine and method for producing packaging cushioning from sheets of a selected substrate, such as paper.

Machines for producing packaging cushioning from paper are well-known in the art. Such machines generally operate by pulling a web of paper from a roll, manipulating the paper web in such a way as to convert the paper into packaging cushioning, and then severing the cushioning into cut sections of a desired length.

While such machines are widely used and have been commercially successful, in many applications, there is a need for improved functionality. For example, paper rolls tend to be quite heavy and cumbersome to lift and load onto cushion conversion machines. Although the volume of cushioning that can be produced from a roll of paper tends to off-set the weight disadvantage for high-volume packaging operations, for lower-volume packaging operations, a lighter, easier-to-handle alternative would be preferred.

Moreover, while severing mechanisms in roll-fed machines provide a workable means for producing cushions of a desired length, such mechanisms present ongoing safety concerns, in both the design and operation of such machines.

As a result, Sealed Air Corporation (US), assignee of the present invention, has developed a machine that produces packaging cushions of a desired length without the need for a severing or perforation mechanism, by joining individual sheets of paper together in such a way that packaging cushions having any desired length can be produced. Such machine, which is described in U.S. patent application Ser. No. 12/583,749, also allows the density of the resultant packaging cushions to be varied as desired to suit the weight or nature of the objects being packaged. This is accomplished by overlapping the sheets to a desired extent, in order to achieve a desired density in the resultant packaging cushions.

One area for improvement that has been identified with the '749 machine concerns the tracking and handling of the paper sheets, particularly when making higher-density packaging cushions. In general, the density of the packaging cushions is proportional to the degree of overlap between successive sheets. Thus, the greater the degree of overlap between adjacent sheets, the higher will be the density of the resultant cushion. It has been found, however, that above a certain point of overlap, the increased resistance to forward movement of the paper sheets results in poor tracking, rippling, and then jamming of the sheets, resulting in the necessity of shutting down the machine to clear the jams, which causes paper to be wasted and production time to be lost.

Accordingly, there is a need in the art for an improvement to sheet-fed packaging-cushion machines, which will reduce or prevent paper jams while still allowing higher-density packaging cushions to be produced.

SUMMARY OF THE INVENTION

That need is met by the present invention, which, in one aspect, provides a machine for producing packaging cushioning, comprising:

a. a first feed mechanism for successively feeding sheets of a substrate at a first speed, the first feed mechanism including a motor and a power supply therefor, wherein the motor is

capable of drawing a varying amount of electricity from the power supply when the first feed mechanism feeds the sheets;

b. a second feed mechanism for receiving the sheets from the first feed mechanism and feeding the sheets at a second speed;

c. a control unit for controlling at least one of the first and second speeds to produce a desired degree of overlap between successive sheets; and

d. a sensor to measure the amount of electricity drawn by the motor, the sensor being structured and arranged to generate a signal, which is indicative of the amount of electricity drawn by the motor, and communicate the signal to the control unit,

wherein, the control unit is structured and arranged to modulate the amount of electricity that the motor draws from the power supply when the signal from the sensor has a value that is greater than or equal to a predetermined value.

Advantageously, by measuring the amount of electricity drawn by the motor, comparing this to a predetermined value, which is indicative of the onset of the a paper jam, and then modulating the amount of electricity that the motor can draw, a desired degree of overlap, leading to a desired packaging-cushion density, can still be achieved, but with a reduced likelihood of sheet misalignment and jamming.

These and other aspects and features of the invention may be better understood with reference to the following description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic view of a machine for producing packaging cushioning in accordance with the present invention;

FIGS. **2-6** are similar to FIG. **1**, and show the machine in various stages of packaging cushion production;

FIG. **7** is a plan view of an alternative machine in accordance with the present invention;

FIG. **8** is a perspective view of the machine shown in FIG. **7**, along lines **8-8**;

FIGS. **9**A and **9**B are similar to FIG. **7**, and show the illustrated machine in two different stages of packaging cushion production;

FIG. **10** is a plan view of a connected string of packaging cushion units as produced in FIG. **9**B;

FIG. **11** a cross-sectional view of the string of packaging cushion units shown in FIG. **10**, taken along lines **11-11**;

FIG. **12** is similar to FIG. **10**, except one of the packaging cushion units is separated from the connected string of packaging cushion units; and

FIG. **13** is a schematic block diagram, which illustrates a control system for reducing or eliminating paper jams in the machines illustrated in FIGS. **1-12**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** schematically illustrates a machine **10** in accordance with the present invention for producing packaging cushioning. Machine **10** comprises a first feed mechanism **12**, a second feed mechanism **14**, and a control unit **16**.

As shown in FIGS. **2-6**, first feed mechanism **12** successively feeds sheets **18** of a substrate at a first speed, which is represented by arrow **20** (FIG. **2**).

Second feed mechanism **14** receives the sheets **18** from the first feed mechanism **12**, and conveys the sheets at a second speed, which is represented by arrow **22** (FIG. **3**). The conveyance of the sheets **18** by second feed mechanism **14** may be effected in such a manner that the sheets are converted into packaging cushion units **24**, e.g., by compressing and/or crumpling the sheets as shown. Thus, in some embodiments, the second feed mechanism **14** may function as a 'crumpling mechanism.'

Control unit **16** controls at least one of the first and second speeds **20**, **22** to produce a desired degree of overlap **26** between successive sheets **18** (FIG. **3**). Such overlap **26**, e.g., in combination with the compression and/or crumpling of the sheets in second feed mechanism **14**, may be employed to generate a connected series **28** of packaging cushion units **24** (FIGS. **4**-**6**). The connected series **28** of packaging cushion units **24** may be structured to have a density that is proportional to the degree of overlap **26** between successive sheets **18**.

Sheets **18** may comprise any type of material desired for use in packaging cushions, including paper, e.g., kraft paper, fiberboard, thermoplastic film, etc., including recycled forms of the foregoing materials, as well as combinations thereof, e.g., laminated paper, coated paper, composite paper, etc. The sheets may have any desired shape, e.g., square, rectangular, etc., with any desired dimensions, e.g., a 20 inch length dimension and a 15 inch width dimension.

Sheets **18** may be arranged for supply to machine **10** in any convenient form, e.g., as a stack **30** as shown, or in shingled, random, or individual form, etc., as desired. When sheets **18** are arranged as a stacked supply **30** as shown, machine **10** may further include a supply tray **32**, which is configured and dimensioned for holding the sheets in a stacked arrangement of desired height, i.e., to accommodate a desired maximum number of sheets **18** in stack **30**. When such an embodiment is employed, first feed mechanism **12** may be disposed and configured for feeding the sheets **18** from supply tray **32** to second feed mechanism **14**. As such, the first feed mechanism **12** may comprise a first feed roller **34** to advance the sheets **18** from the supply **30** thereof, and a second feed roller **36** to receive the sheets from the first feed roller **34** and feed the sheets into second feed mechanism **14**.

The first feed roller **34** may be associated with a motor, schematically designated as motor "M**3**" in the drawings, to drive the rotation of the feed roller. The feed roller **34** may be in a fixed position relative to tray **32**, with the tray including a movable tray base **38**, e.g., pivotally movable as shown, which may be biased towards feed roller **34**, e.g., via spring **40**. In this manner, as the stacked supply **30** of sheets **18** depletes, the sheets are continuously urged against the feed roller **34** so that the feed roller can continue to advance the sheets sequentially from the stack.

FIGS. **2**-**6** illustrate tray **32** with a relatively full stack **30**, such that spring **40** is fully compressed and tray base **38** is substantially aligned with the bottom **42** of tray **32**. The pivot point for tray base **38**, e.g., hinge **41** as shown, may be placed at any desired location along the bottom **42** of tray **32**, e.g., opposite from spring **40** as shown or, e.g., closer to spring **40** such that the movable tray base **38** is shorter than as shown.

Instead of, or in addition to, a movable tray base **38**, the first feed roller **34** may be movably biased towards the stack **30**.

First feed roller **34** may be accompanied by as many additional feed rollers as necessary to advance the sheets **18**. For example, two or more feed rollers **34** may be arrayed across the width of the sheets **18**, e.g., as shown in FIG. **8** (wherein first feed roller **34** is shown as a pair **34***a, b* of such feed rollers).

As shown in the illustrated embodiment, the second feed roller **36** is positioned to receive the sheets **18** from first feed roller **34**, e.g., via guide member **44**, and then feed the sheets into the second feed mechanism **14**. The second feed roller **36** may be associated with a motor, schematically designated as motor "M**1**" in the drawings, to drive the rotation of the feed roller. As an alternative to the illustrated embodiment in which separate motors M**3** and M**1** are employed to drive the rotation of the first and second feed rollers **34** and **36**, respectively, a single motor may be employed to drive the rotation of both the first and second feed rollers **34** and **36**, e.g., via appropriate linkage, which may include drive belt(s), drive chain(s), drive axel(s), etc. Such an alternative embodiment is illustrated schematically in FIG. **2**, wherein motor M**1** drives the rotation of both the first and second feed rollers **34**, **36**.

Second feed roller **36** may be accompanied by as many additional feed rollers as necessary to advance the sheets **18**. For example, two or more feed rollers **36** may be arrayed across the width of the sheets **18**, e.g., as shown in FIG. **8** (wherein second feed roller **36** is shown as a pair **36***a, b* of feed rollers).

A backing member **46** may be included, to provide a support against which second feed roller **36** rotates, to thereby facilitate the feeding of sheets **18** into second feed mechanism **14**. Backing member **46** may be a static member, which provides frictional resistance to the rotation of roller **36** such that the sheets **18** are compressed between the roller **36** and backing member **46** while passing therebetween, with the sheets making sliding contact with the member **46**. Alternatively, backing member **46** may be a rotational member, which rotates passively via rotational contact with the driven roller **36**. As a further alternative, the relative position of the second feed roller **36** and backing member **46** may be switched such that the driven roller **36** is beneath the backing member **46**. This orientation may be particularly convenient when a single motor is employed to power the rotation of both the first and second feed rollers.

As may be appreciated, first feed mechanism **12** generally defines a path of travel along which the sheets **18** move between the supply **30** of the sheets and the second feed mechanism **14**. As mentioned briefly above, the first feed mechanism **12** may further include guide member **44**, which may be included to facilitate the movement of the sheets along the travel path, e.g., by directing the movement of the sheets from the first feed roller **34** to the second feed roller **36**.

The guide member **44** may be structured and arranged to change the movement of the sheets **18** on the travel path, e.g., from a first direction **48**, in which the sheets are fed from supply/stack **30**, to a second direction **50**, in which the sheets are crumpled (FIG. **2**). Advantageously, this allows the machine **10** to have a compact configuration or 'footprint,' e.g., in which the supply tray **32** with sheet supply **30** is positioned beneath second feed mechanism **14** as shown.

In the presently illustrated embodiment, the second feed mechanism **14**, second feed roller **36**, backing member **46**, and motors M**1**, M**2** may be contained within a housing **54** (shown in phantom). The first direction **48** may be substantially parallel to and substantially opposite from the second direction **50** (see, FIG. **2**), such that the housing **54** may be positioned substantially directly above the supply tray **32**, e.g., in a stacked configuration as shown. Guide member **44** may thus define an arcuate path of travel for sheets **18** as shown, e.g., with approximately 180 degrees of curvature. With such a structure, secondary or inner guide member **45** may also be included, and may have a complementary position on the inside of the arcuate path defined by guide member **44** as shown.

In the above-described embodiment, the second feed roller **36** receives the sheets **18** indirectly from the first feed roller **34**, e.g., via guide member **44**. Alternatively, the first feed mechanism **12** may define a more linear path of travel for the sheets **18**, in which the sheets are advanced from supply **30** in substantially the same direction as they are crumpled in second feed mechanism **14**. This may be accomplished, e.g., by positioning the supply tray **32** beside, rather than beneath, housing **54**. In such embodiment, the second feed rollers may receive the sheets **18** substantially directly from the first feed roller **34**, i.e., with no intervening guide member **44**. More generally, supply tray **32** and housing **54** may have any desired relative orientation. For example, the tray **32** and housing **54** may be positioned at 90 degrees to one another, e.g., with the housing **54** having a substantially horizontal orientation and the tray **32** having a substantially vertical orientation.

Feed rollers **34**, **36** may comprise any material suitable for conveying sheets **18**, such as metal (e.g., aluminum, steel, etc.), rubber, elastomer (e.g., RTV silicone), urethane, etc., including combinations of the foregoing materials. As an alternative to wheel-type rollers as shown, one or both feed rollers **34**, **36** may comprise one or more counter-rotating drive belts, drive bands, etc. As a further alternative to feed rollers **34**, **36**, or in addition thereto, first feed mechanism **12** may convey the sheets **18** via any suitable sheet-handling means, including pneumatic conveyance, electrostatic conveyance, vacuum conveyance, etc.

Second feed mechanism **14** may comprise a pair of compression members **52***a* and **52***b* that convert the sheets **18** into packaging cushion units **24** by compressing and/or crumpling the sheets therebetween. The compression members **52***a, b* may comprise a pair of counter-rotating wheels, belts, etc., or, as shown, a pair of counter-rotating gears, which may have radially-extending teeth **56** that mesh together to effect the crumpling of the sheets **18**, e.g., as illustrated in FIGS. **3**-**6**. The teeth **56** are preferably sized and shaped to convey and crumple the sheets **18** without tearing the sheets. The compression members **52***a, b* and teeth **56** may be formed of any material capable of conveying and crumpling the sheets **18**, and preferably with sufficient toughness to withstand wear but without causing damage to the sheets **18**. Many suitable materials exist. Examples include polymeric materials such as ultra-high molecular weight polyethylene (UHMWPE), polyimide, fluorocarbon resins such as polytetrafluoroethylene (PTFE) and perfluoropropylene, acetal resins, i.e., resins based on polyoxymethylene, including homopolymers (e.g., Delrin® brand polyoxymethylene), copolymers, and filled/impregnated grades, such as PTFE-filled acetal resins; various metals such as aluminum, steel, etc.; metals with low-COF coatings, e.g., anodized aluminum or nickel impregnated with low-COF polymers such as PTFE or other fluorocarbon resins; and mixtures or combinations of the foregoing.

The compression members **52***a, b* may connect the packaging cushion units **24** together by compressing and/or crumpling the sheets **18** at the overlap **26** between successive sheets. That is, the action of compressing/crumpling two overlapped sheets together has the effect of joining the sheets together at the overlapped portions of the sheets. By controlling the first speed **20** relative to the second speed **22**, the overlap **26** can have any desired degree. Preferably, the overlap **26** is only a partial overlap such that a chain of the sheets **18**, as converted into packaging cushion units **24**, may be connected together, i.e., to form connected series **28**.

FIGS. **2**-**6** illustrate a sequence of events that lead to the conversion of sheets **18** into packaging cushion units **24**, and to their being connected together to form a connected series **28** of the packaging cushion units **24**.

FIG. **2** illustrates the beginning of the production process, in which first feed roller **34** of first feed mechanism **12** engages the upper-most sheet **18***a* in stack **30**, and rotates in the direction of the indicated arrow to move the sheet in first direction **48**. Sheet **18***a* immediately encounters guide member **44**, which causes it to change course to second direction **50**, thereby leading the sheet **18***a* into the nip between second feed roller **36** and backing member **46**. Motor M**1** is powering the rotation of the second feed roller **36**, as indicated by the rotational arrows associated with the feed roller **36** and backing member **46**, such that sheet **18***a* is fed towards second feed mechanism **14** at first speed **20**. The magnitude of first speed **20** is determined by the output of motor M**1**. If a separate motor M**3** is employed (FIG. **3**), motors M**1** and M**3** may be synchronized such that the speed at which the sheets **18** are advanced from supply **30** is the same as the speed **20** at which the sheets are fed to the second feed mechanism **14**. Alternatively, by operating the first and second feed rollers **34**, **36** at different speeds, compressive or tensional forces may be imparted on the sheets **18** prior to their conveyance to the second feed mechanism **14**. As a further alternative, as shown in FIG. **2**, only one motor M**1** may be employed in place of the separate motors M**1** and M**3**, with the rotational output of motor M**1** being transmitted to both the first and second feed rollers **34**, **36**.

The feeding of the sheets **18** by the first feed mechanism **12** may be facilitated by including a second guide member, which may include upper and lower guide plates **58***a, b*. As shown, guide plates **58***a, b* may be positioned between second feed roller **36** and second feed mechanism **14**, and arranged to form a passage **60** therebetween to guide the movement of the sheets **18** as they are fed by the second feed roller **36** and into the second feed mechanism **14**.

In FIG. **3**, a second sheet **18***b* has been withdrawn from supply stack **30** by first feed roller **34**, transferred to second feed roller **36**, and is being fed through passage **60** towards second feed mechanism **14** by the second feed roller **36** at first speed **20**. At the same time, the first sheet **18***a* has reached second feed mechanism **14** and is being crumpled and conveyed thereby at second speed **22**. Second speed **22** results from the rotational speed at which the compression members **52***a, b* counter-rotate against one another, as indicated by the rotational arrows. The rotational speed of the compression members **52***a, b*, in turn, is determined by the output of motor M**2**.

As noted above, at least one of the first and second speeds **20**, **22** may be controlled to produce a desired degree of overlap **26** between successive sheets **18**, thereby generating the connected series **28** of packaging cushion units **24**. As shown in FIG. **3**, the overlap **26** is produced between the trailing end **62** of sheet **18***a* and the leading end **64** of sheet **18***b*. Such overlap may result from a speed differential between first speed **20** and second speed **22**.

For example, the second feed mechanism **14** and second feed roller **36** may be operated such that second speed **22** is slower than first speed **20**. In this manner, when sheet **18***a* is released from first feed mechanism **12** and engaged only by second feed mechanism **14**, it will be moving at the slower second speed **22**. Conversely, while the next sheet **18***b* is engaged only by the first feed mechanism **12**, i.e., prior to the leading end **64** thereof reaching the second feed mechanism **14**, it (sheet **18***b*) moves at the relatively higher first speed **20**. As a result, the leading end **64** of sheet **18***b* overtakes and slides over or under the trailing end **62** of sheet **18***a*, to form overlap **26** as shown. The degree of the overlap **26** will continue to increase until the leading end **64** of sheet **18***b* reaches the second feed mechanism **14** and/or sheet **18***b* is released from first feed mechanism **12**.

That is, as shown in FIG. **4**, once the leading end **64** of sheet **18***b* becomes engaged by the second feed mechanism **14**, the speed at which the sheet **18***b* moves through machine **10** will decrease from first speed **20** to second speed **22**. At that point, with both sheets **18***a, b* moving at the same speed, i.e., speed **22**, and both sheets being engaged by second feed mechanism **14**, no further relative movement of sheets **18***a, b* will occur, such that no further increase in the overlap **26** will occur. Thus, as shown, the overlapped section **26** of successive sheets **18***a* and **18***b* are crumpled or compressed together in second feed mechanism **14**, which has the effect of joining the trailing end **62** of sheet **18***a* to the leading end **64** of the following sheet **18***b*. This, in turn, results in the connection of the packaging cushion unit **24***a*, as formed by the crumpled sheet **18***a*, to the next packaging cushion unit **24***b*, which is being formed in FIG. **4** from sheet **18***b* as it is crumpled or otherwise compressed in second feed mechanism **14**.

In FIG. **5**, the connection process between packaging cushion units **24***a* and **24***b* is complete in that the overlap **26** between the respective successive sheets **18***a* and **18***b* has moved through and past second feed mechanism **14**. The remainder of sheet **18***b* is being crumpled to complete its conversion into packaging cushion unit **24***b*. The resultant series **28** of connected packaging cushion units is being conveyed out of machine **10**, e.g., via outlet **66** in housing **54**. If desired, a receptacle, e.g., a storage bin or the like (not shown), may be employed for containment of the connected series **28** of packaging cushion units **24** until such cushion units are needed for use. In such case, the outlet **66** may be configured to guide the connected series **28** directly into the receptacle.

Also in FIG. **5**, first feed roller **34** of first feed mechanism **12** engages the next sheet **18***c* in stack **30**, and advances it towards second feed roller **36** via guide member **44**. The sheet **18***c* then moves through the nip between second feed roller **36** and backing member **46** at first speed **20** towards the preceding sheet **18***b*, which is moving at a slower second speed **22** as a result of its engagement by second feed mechanism **14**. The speed differential between speeds **20** and **22** will result in leading end **64** of sheet **18***c* overtaking the trailing end **62** of the preceding sheet **18***b* to form another overlap **26** (shown in FIG. **6**), as described above relative to FIG. **3**.

In FIG. **6**, an overlap **26** has formed between the leading end **64** of sheet **18***c* and the trailing end **62** of the preceding sheet **18***b*. Such overlap **26** is being crumpled together in second feed mechanism **14**, which has the effect of joining the trailing end **62** of sheet **18***b* to the leading end **64** of the following sheet **18***c*. This, in turn, results in the connection of the packaging cushion unit **24***b*, as formed by the crumpled sheet **18***b*, to the next packaging cushion unit **24***c*, which is being formed from sheet **18***c* as it is crumpled in second feed mechanism **14**.

As also shown in FIG. **6**, as the supply **30** of sheets **18** in tray **32** depletes, spring **40** extends, and thereby causes the tray base **38** to pivot upwards to maintain the uppermost sheet in the supply stack in contact with first feed roller **34**.

The foregoing process may continue for as long as desired, e.g., until supply **30** of sheets **18** in tray **32** is depleted, in order to add as many additional packaging cushion units **24** as desired to the connected series **28**.

First speed **20** and/or second speed **22** may be controlled by controlling the rotational speed of the second feed roller **36** and/or that of the compression member **52***a* and/or b, respectively. Control unit **16** may thus be in electrical communication with motor **M1** and/or **M2**. Thus, for example, the speed at which motor **M2** drives the rotation of the compression members **52***a, b* may be fixed, while control unit **16** may be operably linked to motor **M1** to cause the motor to provide a range of controllable output speeds which, in turn, produce a range of rotational speeds for second feed roller **36**. Alternatively, the speed of motor M**1** may be fixed while motor M**2** is a variable speed motor, the speed of which is controlled by control unit **16**. This alternative may be selected when control system **108** is included, as described below (FIG. **13**). As a further alternative, both motors M**1** and M**2** may be variable-speed motors, and both may be operably linked to control unit **16**, e.g., via respective control/power-supply wires **68** and **70** as shown, so that the speed of one or both of motors M**1**, M**2** may be controlled.

Control unit **16** may be in the form of a printed circuit assembly, and include a controller, e.g., an electronic controller, such as a microcontroller, which stores pre-programmed operating codes; a programmable logic controller (PLC); a programmable automation controller (PAC); a personal computer (PC); or other such control device which allows the speed of motors M**1** and/or M**2** to be controlled. Commands may be supplied to the control unit **16** via an operator interface or the like, or may be supplied remotely or substantially completely via pre-programming, i.e., full automation.

Control unit **16** may control the operation of motor M**1** and/or M**2**, thereby controlling at least one of the first and second speeds **20**, **22**, automatically, manually, or via a combination of both automatic and manual control. In some embodiments, control unit **16** may be configured to receive input from an operator, i.e., from an operator interface such as a foot pedal, hand switch, control panel, etc., including combinations of the foregoing. An operator may thus be able to select a desired degree of overlap between successive sheets, as well as the number of packaging cushion units to be connected in a given series of such units.

Thus, for example, control unit **16** may include, or be electronically associated with, an operator input device, e.g., a switch or the like (not shown), which allows the operator to select a desired degree of overlap between successive sheets. A two-position switch, for example, could allow an operator to choose between a 'low-density' mode of operation and a 'high-density' mode of operation.

In the 'low-density' mode, control unit **16** would command machine **10** to connect packaging cushion units **24** together with a minimum degree of overlap, e.g., just enough to form a connection, such as between about 1 and about 3 inches of overlap between successive sheets. The advantage of the low-density mode is that a minimal amount of sheets **18** are used for a given length of connected packaging cushion units **24**, thus providing an economical mode of operation as would be appropriate, e.g., for the packaging of lighter-weight objects. As an example, for sheets **18** having a length of 20 inches and a width of 17 inches, such low-density/minimal overlap mode was achieved when machine **10** was configured as alternative machine **10'** as shown in FIGS. **7-9**, and was operated at a first speed **20** of about 40 inches/second and a second speed **22** of about 26 inches/second, or a first speed **20**/second speed **22** ratio of about 1.5. Such speed ratio of about 1.5 resulted in an overlap **26** of about 2 inches.

In the 'high-density' mode, control unit **16** would command machine **10** to connect packaging cushion units **24** together with a greater degree of overlap, e.g., between about 4 and about 6 inches of overlap between successive sheets. Although a greater number of sheets **18** are used to produce a given length of connected packaging cushion units **24**, i.e., as compared with the low-density mode, an increase in the density of the packaging cushions often becomes necessary when the packaging application changes, e.g., to properly protect higher-weight objects in a package. As an example, for sheets **18** having a length of 20 inches and a width of 17 inches, such high-density/higher overlap mode was achieved when machine **10** was configured as alternative machine **10'** as shown in FIGS. **7-9**, and was operated at a first speed **20** of about 28 inches/second and a second speed **22** of about 12 inches/second, resulting in a speed differential of about 16 inches/minute. Such speed differential of 16 inches/minute resulted in an overlap **26** of about 5 inches. Stated differently, the speed ratio between first speed **20** (28 inches/second) and second speed **22** (12 inches/minute) in this example was about 2.33.

An alternative control scheme is to enable the operator to select any desired differential or ratio between first speed **20** and second speed **22**, between pre-set minimum and maximum amounts. For example, a potentiometer that adjusts the speed ratio between first speed **20** and second speed **22** may be employed, wherein a setting of "0" (zero) corresponds to the minimum allowed differential between speeds **20** and **22** (minimum allowed overlap between successive sheets/minimum density), and "10" (ten) corresponds to the maximum allowed differential between such speeds (maximum allowed overlap/maximum density). Another alternative would be to have a multitude of preset density conditions, which the operator can select by switching between predetermined ratio settings using a multi-position switch.

As a further alternative, control unit **16** may be configured to allow an operator to set the operating speeds of motor M**1** and/or M**2** manually, e.g., as the sole means of control. In such embodiment, control unit **16** may be a simple device containing, for example, a multi-position switch or dial to control the speed of motor M**1**/second feed roller **36** and/or a second switch or dial to control the speed of motor M**2**/compression members **52***a, b*.

As may be appreciated, the ability to easily change the density of the connected series **28** of packaging cushion units **24** as needed, i.e., without having to change to a different type/weight of sheet, or add sheets from a different source, in order to suit the changing needs of differing packaging applications is a highly advantageous feature of the present invention.

The control unit **16** may further include or be associated with a dial or the like, which allows an operator to select a desired number of packaging cushion units to be produced upon a further command from the operator, such as the actuation of a foot pedal or hand switch (not shown) in electrical communication with the control unit. Such actuation by the operator will then result in machine **10** commencing operation and continuing to operate until the selected number of packaging cushion units are produced.

In one mode of operation, control unit **16** may be programmed by specifying, via appropriate input command, the diameter of both the first and second feed rollers **34**, **36**, as well as the length of the sheets **18**. When control unit **16** is operably linked to motor M**1** as described above (i.e., via control/power-supply wire **68**), and optionally also to motor M**3** (control wire not shown; M**1** and M**3** may be the same motor) the speed of motors M**1** and M**3** may be controlled by control unit **16**. Based on the operational run-time and rotational-speed commands that the control unit has given to each of the feed rollers **34**, **36**, coupled with any necessary feedback to verify that such commands have been carried out, the control unit **16** will "know", through simple calculations, the approximate number of sheets **18** that have been fed by the first feed roller **34** and by the second feed roller **36**. In this manner, control unit **16** can maintain an approximate count of the number of packaging cushion units produced each time that an operator commands the machine to run, e.g., so that the control unit **16** can automatically command the machine to stop when the requested number of cushion units has been produced. Other means for counting the number of cushion units produced, which will generally be more precise but also more costly, are also possible, e.g., photo-eyes, motor encoders, etc. Such devices may be employed to provide feed-back to control unit **16** regarding the number of sheets and/or cushion units that have passed a given point in machine **10**.

Control unit **16** may include or be associated with a further operator input device, e.g., a switch or the like, which allows the operator to select an 'eject' mode, wherein machine **10** ejects the resultant string of packaging cushion units, e.g., into a bin or other receptacle, or a 'hold' mode, wherein machine **10** holds the last packaging cushion unit produced in a string of cushions in the outlet **66** for manual removal by the operator.

For example, with reference to FIG. **6**, if the operator selects a string of about three (3) packaging cushion units **24** to be produced, and also selects the 'eject' mode, control unit **16** will command motor M**3** and then M**1** to discontinue operations once it (the control unit **16**) determines that sheets **18***a-c* have passed through the first and second feed rollers **34**, **36**. In this case, the resultant series **28** of three (3) connected packaging cushion units would be ejected out of machine **10** via conveyance by second feed mechanism **14**, which the control unit **16** will command to continue to operate for a predetermined time (based on speed **22** and the pre-programmed length of sheets **18**) after second feed roller **36** ceases to operate.

Using the same example, if the operator selects the 'hold' mode, an additional sheet, e.g., a fourth sheet **18***d* (not shown), will be connected to sheet **18***c* (or to the last sheet to be included in the series) via an overlap **26** (also not shown), and the control unit **16** will command all motors M**1**-M**3** to stop once that overlap has cleared the compression members **52***a, b*, such that the resultant series **28** of about three (3) connected packaging cushion units is extending from outlet **66**, connected to a partially formed cushion unit formed by the next sheet (e.g., **18***d*), which is held in the machine by the compression members **52***a, b*. To remove such connected series **28**, the operator simply pulls cushion unit **24***c* to release it from the overlapped connection **26** with the partially-formed cushion unit formed from the next sheet (e.g., **18***d*).

As illustrated in the drawings, second feed mechanism **14** receives sheets **18** indirectly from first feed mechanism **12**, i.e., via guide plates **58***a, b*, which are interposed between the first feed mechanism **12** and the second feed mechanism **14**. Alternatively, such guide plates **58***a, b* may be omitted such that the second feed mechanism **14** receives the sheets directly from the first feed mechanism **12**.

As a further alternative, a machine in accordance with the present invention may include a convergence device in place of guide plates **58***a, b*. As shown in FIGS. **7-9**, in alternative machine **10'**, at least part of convergence device **72** may be positioned between first feed mechanism **12** and second feed mechanism **14** for reducing the width dimension of the sheets **18**. As shown, convergence device **72** may be in the form of a chute, with a relatively wide entrance portion **74** and a relatively narrow exit portion **76**. Second feed roller **36** may be in the form of a pair of such feed rollers **36***a, b*, which may be positioned at or near the entrance portion **74** of convergence device **72**, and driven by motor M**1** via a common drive axle **78**. With this arrangement, the first feed mechanism **12** feeds the sheets **18** into second feed mechanism **14** by pushing the sheets through the convergence device **72** and then into the second feed mechanism **14**.

Exit portion **76** may be positioned adjacent the second feed mechanism **14**, such that sheets **18** exiting the convergence device **72** are directed into the second feed mechanism. A guide channel **80** may extend from convergence device **72** as shown, to contain and direct the sheets **18** as they are crumpled or otherwise compressed in mechanism **14**. In alternative machine **10'**, second feed mechanism **14** may thus be positioned within the guide channel **80**, and may be driven by motor M2 via drive axle **82**.

As perhaps best shown in FIG. **8**, convergence device **72** may include opposing side walls **88***a, b*, which converge in a direction leading from the entrance portion **74** to the exit portion **76**, i.e., along second direction **50**. Side walls **88***a, b* may be included as necessary to facilitate the convergence of sheets **18** by helping to contain and direct the sheets as their width is reduced.

As also shown in FIG. **8**, first feed roller **34** may comprise a pair of rollers **34***a, b*, which may be driven by motor M3 via common drive axle **84**. A pair of springs **40**, indicated as springs **40***a, b* in FIG. **8**, may be included to bias tray base **38** towards the feed rollers **34***a, b*. Tray base **38** may be pivotally attached to the bottom **42** of tray **32** via multiple hinges **41***a-c*.

FIG. **9**A is essentially a plan view of FIG. **2**, in that sheet **18***a* is being fed from stack **30** and into second feed mechanism **14** at first speed **20**. In FIG. **9**A, however, machine **10'** includes convergence device **72**, instead of guide plates **58***a, b*, through which sheet **18***a* is being conveyed en route to second feed mechanism **14**.

As may be appreciated, sheets **18** generally have a length dimension and a width dimension, each of which may be the same or different among the various sheets in stack **30**. With respect to sheet **18***a* for example, the width dimension "W1" thereof is shown in FIG. **9**A; the length dimension "L" of the sheets is shown in FIG. **2**. The sheets **18** generally also have a pair of opposed lateral sides **86***a, b* (FIG. **9**A).

Accordingly, when alternative machine **10'** is employed, i.e., with convergence device **72**, the process for making packaging cushioning may further include the step of reducing the width dimension of the sheets. As shown in FIG. **9**A, such width reduction step may occur prior to the crumpling/compression step in second feed mechanism **14**, and may be effected by directing the sheets **18** through convergence device **72**. Thus, as the sheets **18** move from the entrance portion **74** to the exit portion **76** along second direction **50**, the convergence device **72** causes the lateral sides **86***a, b* to converge towards one another.

For example, as shown in FIG. **9**A, the initial width W1 of sheet **18***a* may be slightly less than that of the entrance portion **74** of convergence device **72** so that the sheet can be fed into the device **72**. As the sheet moves along second direction **50**, the lateral sides **86***a, b* of the sheet come in contact with the convergent side walls **88***a, b*. Such convergent contact between the lateral sides **86***a, b* and the side walls **88***a, b* causes the lateral sides **86***a, b* of the sheet to converge towards one another as shown. As a result, upon reaching the exit portion **76** of the convergence device **72**, and then traveling through the guide channel **80**, the width of the sheet is reduced from width W1 to width W2.

The side walls **88***a, b* may be curved as shown in FIG. **8**, or may have any other shape, e.g., square or rectangular, that facilitates the convergence of the lateral sides **86***a, b*. The convergence device **72** may include a bottom surface **90** as shown, and may also include a top surface (not shown), e.g., similar to upper guide plate **58***a* as shown in FIGS. **1-6** with respect to machine **10**. As shown in FIGS. **7-8**, cut-outs **91** in bottom surface **90** may be provided for second feed rollers **36***a, b* and backing members **46**. Alternatively, both the backing members **46** and cut-outs **91** may be omitted as shown in FIGS. **9**A-B, wherein feed rollers **36***a, b* drive the sheets **18** against the bottom surface **90** of convergence device **72**.

FIG. **9**B is essentially a plan view of FIG. **5**, except that convergence device **72** is used instead of guide plates **58***a, b*. Thus, similar to FIG. **5**, in FIG. **9**B the connection process between packaging cushion units **24***a'* and **24***b'*, from respective successive sheets **18***a* and **18***b*, is complete, with the overlap **26***a* between sheets **18***a, b* having moved through and past second feed mechanism **14**. The remainder of sheet **18***b* is being crumpled to complete its conversion into packaging cushion unit **24***b'*. The next successive sheet **18***c* is being fed by first feed mechanism **12** at first speed **20** towards the preceding sheet **18***b*, which is moving at a slower second speed **22** as a result of its engagement by second feed mechanism **14**. The speed differential between speeds **20** and **22** will result in leading end **64** of sheet **18***c* overtaking the trailing end **62** of the preceding sheet **18***b* to form another overlap **26**, e.g., as shown in FIG. **6**.

It may be appreciated that the shape and characteristics of packaging cushion units **24'**, as produced by machine **10'**, are different than those of packaging cushion units **24**, as produced by machine **10**, in that, prior to crumpling, the convergence device **72** of machine **10'** reduces the width dimension W1 of sheets **18**, such that the width of the resultant packaging cushion units **24** is W2. Generally, the convergence device **72** may be configured to effect any desired width reduction in sheets **18**. The ratio of W1:W2 may be, for example, within the range of 10:1 to 1:1, e.g., between about 9:1 to about 2:1, such as between about 8:1 to about 3:1, 7:1 to 4:1, etc.

In the present embodiment, convergence device **72** reduces such width by causing the lateral sides **86***a, b* to converge. For example, the convergence of the lateral sides **86***a, b* may be such that the lateral sides overlap one another and form the sheets **18** into a tube **93** as shown, e.g., with only lateral side **86***a* being visible. As shown, sheet **18***b* has been formed into a tube **93**, and the width thereof is being reduced as it travels towards the exit portion **76** of convergence device **72**. Sheet **18***c* is in the process of being formed into a tube. The differential between its speed **20** and that of sheet **18***b* (i.e., slower speed **22**) will result in leading end **64** of the tube being formed from sheet **18***c* overtaking the trailing end **62** of the tube **93** formed from preceding sheet **18***b*, which will form another overlap of the tubes, i.e., as at **26** in FIG. **9**B.

In the illustrated embodiment, the final width of the packaging cushion units **24** is shown to be essentially the same as that of the outlet **66** of housing **54**, i.e., W2. It should be understood, however, that this is not necessarily the case. For example, the internal structure of housing **54** can be arranged such that the final width of the packaging cushion units **24** is less than the width of the outlet **66**, e.g., as would be the case if the exit portion **76** of convergence device **72** is narrower than outlet **66**.

Regardless of the manner in which the lateral sides **86***a, b* are converged in device **72**, as shown in FIG. **9**B, the second feed mechanism **14** crimps the converged lateral sides, e.g., as the tube **93** passes through the second feed mechanism. This has the effect of causing the resultant packaging cushion unit **24'** to maintain a substantially tubular, i.e., longitudinally-rolled, form.

Referring now to FIGS. **10-11**, the packaging cushion units **24'** will be described in further detail. FIGS. **10-11** show a connected series **28'** of packaging cushion units **24'**, comprising packaging cushion units **24'***a-c*, as made from machine **10'**. A greater or less number of packaging cushion units may be included in any given connected series of such cushions. Each packaging cushion unit **24'** comprises a pair of end regions **92** bounding a central region **94**. As shown, the end regions **92** correspond to the overlap **26** between successive sheets **18**. As indicated collectively in FIGS. **9**B through **11**, second feed mechanism **14** crimps the overlapped end regions **92** of adjacent packaging cushion units **24'** together. This has the effect of connecting the packaging cushion units **24'** to thereby form the connected series **28'**. Thus, in the illustration set forth in FIGS. **10-11**, packaging cushion units **24***a*' and **24***b*' are connected at overlap **26***a*, while packaging cushion units **24***b*' and **24***c*' are connected at overlap **26***b*.

When machine **10'** is employed, the overlapped end regions **26**/**92** may be formed by inserting the leading end **64** of a sheet **18**, which is being formed into a tube **93**, into the trailing end **62** of the preceding sheet that has already been formed into a tube **93**. For example, as shown in FIG. **9**B, sheet **18***c* is being formed into a tube, with the leading end **64** having a cone shape as a result of the converging side walls **88***a, b* of convergence device **72**. As the sheet **18***c* moves towards the preceding sheet **18***b* at speed **20**, the cone-shaped leading end **64** will be inserted into the trailing end **62** of the tube-shaped sheet **18***b*, which is moving at the slower speed **22**.

Thus, the second feed mechanism **14** as employed in machine **10'** crimps both of the following:

1) the converged lateral sides **86***a, b*, which has the effect of causing the resultant packaging cushion unit **24'** to maintain a substantially tubular, i.e., longitudinally-rolled, shape; and

2) the overlapped end regions **26**/**92** of adjacent packaging cushion units **24'**, which has the effect of connecting the packaging cushion units **24'** together as a series **28'**.

Regardless of whether machine **10** or **10'** is employed, the connected series **28**/**28'** of packaging cushion units **24**/**24'** will generally have a density that is proportional to the degree of overlap **26** between successive sheets **18**. Thus, the higher the degree of the overlap **26**, the higher will be the average density of the connected series **28**/**28'** of packaging cushion units. With a higher degree of overlap, more sheets **18** will be present per unit volume of the connected series **28**/**28'** than when the degree of overlap is less.

The degree of overlap **26** is proportional to the speed differential between the first and second speeds **20**, **22**. Thus, the degree of overlap **26**, and therefore the density of the connected series **28**/**28'** of packaging cushion units **24**/**24'**, may be controlled by controlling such speed differential.

Generally, the degree of overlap between any two successive sheets **18** may range from greater than 0% to less than 100%, e.g., between about 1% and about 75% overlap, between about 2% and about 50% overlap, or between about 3% and about 40% overlap, etc. For example, sheets **18** having a width "W**1**" of 17 inches and a length "L" of 20 inches were formed on machine **10'** into a connected series **28'** of packaging cushion units **24'** with an overlap of about 25%, i.e., with about 5 inches of overlap between successive sheets **18**, by employing a first speed **20** of about 28 inches/second and a second speed **22** of about 12 inches/second, resulting in a speed differential of about 16 inches/minute or, stated differently, a speed ratio (first speed:second speed) of 2.33:1. The initial width W**1** of the sheets **18** (17 inches) was reduced to a final width W**2** in the resultant packaging cushion units of 3-3.5 inches, for a W**1**:W**2** ratio of about 5:1. The density of the resultant series **28'** of packaging cushion units **24'** was about 1.4 lbs/ft^3.

When a similar series **28'** of connected packaging cushion units **24'** was formed with an overlap **26** of 2 inches, i.e., a lower degree of overlap than 5 inches as in the previous example, the resultant density of the connected series **28'** was also lower—namely, about 1.2 lbs/ft^3. In this example, the first speed **20** was about 40 inches/second and the second speed **22** was about 26 inches/second.

Referring now to FIG. **12**, a further beneficial feature of the invention will be described. Namely, in accordance with some embodiments of the invention, the packaging cushion units may be connected such that each packaging cushion unit **24**/**24'** is slidingly separable from an adjacent packaging cushion unit **24**/**24'**. As shown in FIG. **12**, packaging cushion unit **24***c*' is being slidingly separated from connected series **28'**. More specifically, packaging cushion unit **24***c*' is being slidingly separated from adjacent packaging cushion unit **24***b*' in the direction of arrows **96**. This may be accomplished by connecting the cushion units **24***b*' and **24***c*' in such a way that the overlapped end regions **92** at which the two cushion units are connected, i.e., at overlap **26***b* in FIGS. **10-11**, are releasable. Such releasable connection may, for example, be effected via a friction fit, which is produced by the crumpling of sheets **18** at the overlap **26** between successive sheets.

A friction fit between adjacent packaging cushion units may be achieved via the use of the second feed mechanism **14** as described above, i.e., comprising counter-rotating compression members **52***a, b*, each of which have cooperative teeth **56** that intermesh together. The intermeshing teeth **56** may be shaped and arranged to crimp the sheets **18** so as to form an alternating series of convex impressions **98** and concave impressions **100** in packaging cushion units **24'**, e.g., 'peaks' 98 and 'valleys' 100, as perhaps best shown in FIG. **11**. The width of the compression members **52***a, b* may be substantially equal to the final width W**2** of the packaging cushion units **24'** so that the peaks and valleys **98**, **100** extend transversely across substantially the entire width W**2** of the units **24'**. Alternatively, as shown in FIGS. **9**A/**9**B, the width of the compression members **52***a, b* may be less than width W**2**, so that the peaks and valleys **98**, **100** extend transversely across only a part of the width W**2** of the packaging cushion units **24'**, e.g., across a center region **102** (FIG. **12**), leaving longitudinally-extending outer regions **104** substantially without impressions **98**, **100**.

In the overlap areas **26**, the peaks and valleys **98**, **100** of the crimped end regions **92** of adjacent packaging cushion units **24'** serve to connect the units **24'** together with a friction fit, which also permits the units **24'** to be slidingly separated from one another, e.g., as shown in FIG. **12**. In addition to the degree of overlap **26**, the coefficient of friction of sheets **18**, etc., the depth of the peaks and valleys **98**, **100** will determine the strength of the connection between adjacent packaging cushion units **24**/**24'**. The depth of the peaks and valleys **98**, **100**, is based, at least in part, on the extent of intermeshing of the teeth **56** of counter-rotating compression members **52***a, b*. Thus, in addition to the selection of the degree of overlap **26** and the type of sheets **18**, the depth of the peaks and valleys **98**, **100** may be established to provide a desired amount of connection strength between adjacent packaging cushion units, so that any two units may be disconnected from one another upon the application of a desired amount of tensional force, e.g., manual force, as exerted, e.g., in the direction of arrows **96** in FIG. **12**.

Advantageously, packaging cushions of any desired size, e.g., comprising a desired number of connected packaging cushion units **24**/**24'**, may be created by separating two of the packaging cushion units from one another to thereby remove a packaging cushion from the connected series **28**/**28'** of packaging cushion units. With reference to FIG. **12**, for example, a packaging cushion **106** may comprise connected packaging cushion units **24***a*' and **24***b*'. As may be appreciated, the density of packaging cushion **106** varies along its length dimension (parallel to arrows **96**), with the density being higher in the overlap area **26***a* (at which the cushion units are connected) than in the remaining parts of the cushion

106. This is advantageous in packaging applications in which an object to be packaged has a relatively heavy or protruding portion; the higher density part **26** of the packaging cushion can be placed in contact with such heavy or protruding portion to provide extra support thereto.

Referring now to FIG. **13**, an embodiment of control unit **16** will be described in further detail, in conjunction with, e.g., as a component of, a control system **108** for machine **10** and/or **10'**. As noted above, control unit **16** controls at least one of the first and second speeds **20**, **22** to produce a desired degree of overlap between successive sheets **18**. As also noted, first feed mechanism **12** may include motor M**1**, and optionally also motor M**3**, to power the rotation of first feed roller **34** and/or second feed roller **36**, such that the first feed mechanism **12** can successively feed sheets **18** at first speed **20** to second feed mechanism **14**, which feeds the sheets at second speed **22**. For simplicity, the embodiment shown in FIG. **2**, i.e., wherein motor M**1** powers the rotation of both first and second feed rollers **34**, **36**, is represented in FIG. **13**.

In the embodiment schematically illustrated in FIG. **13**, motor M**1** receives power via power supply **110**. Motor M**1** is of a type that is capable of drawing a varying amount of electricity from power supply **110** when first feed mechanism **12** feeds sheets **18**. For example, as first feed mechanism **12** feeds sheets **18**, the power requirement of motor M**1** will increase slightly each time a sheet **18** is moved forward by first feed roller **34** and by second feed roller **36**, causing motor M**1** to draw slightly more electricity from power supply **110** than when no sheets are being fed. Thus, when machine **10/10'** feeds only one sheet **18** at a time, e.g., makes packaging cushion units from only one sheet, the amount of electricity drawn by motor M**1** will vary intermittently between a 'feed amount' and a 'non-feed amount.'

On the other hand, when machine **10/10'** connects packaging cushion units together by forming an overlap **26** between successive sheets, the load on motor M**1** increases more than when feeding one sheet at a time, as additional force is required to push each sheet under or over a portion of the preceding sheet in the machine to form the overlap, primarily as a result of frictional resistance to such action. In this instance, the variability in the amount of electricity drawn by motor M**1** will be greater than when the machine feeds only one sheet at a time, e.g., will vary, in increasing order, between a 'non-feed amount,' a 'feed amount,' and an 'overlap amount.'

As noted above, machine **10/10'** can change the density of the connected series **28/28'** of packaging cushion units **24/24'**, e.g., between a 'low-density mode,' in which a minimal degree of overlap **26** is employed, and a 'high-density mode,' in which a maximal degree of overlap is effected, with any desired density therebetween. Generally, the amount of electricity that motor M**1** draws from power supply **110** will be directly proportional to the overlap/density that is created between successive sheets **18**/packaging cushion units **24**.

The inventors have determined that, above a certain point of overlap, e.g., in seeking to create higher-density packaging cushions, the increased resistance to forward movement of the paper sheets results in poor tracking, rippling, and then jamming of the sheets, resulting in the necessity of shutting down the machine to clear the jams. The point at which such jamming occurs can vary from machine to machine, but can be determined empirically and quantified by the amount of electricity drawn by motor M**1** at the 'jamming point.'

Accordingly, control system **108** may include a sensor **112**, as part of control unit **16** or as a separate component acting in conjunction with control unit **16**, to measure the amount of electricity drawn by motor M**1**. As indicated in FIG. **13**, sensor **112** may be structured and arranged to generate a signal **114**, which is indicative of the amount of electricity drawn by motor M**1**, and communicate the signal **114** to the control unit **16**. Based on signal **114**, control unit **16** may thus modulate the amount of electricity that motor M**1** draws from power supply **110** when the signal **114** from sensor **112** has a value that is greater than or equal to a predetermined value, e.g., wherein such predetermined value corresponds to the empirically-determined 'jamming point.'

FIG. **13** illustrates an arrangement by which the control unit **16** may modulate the amount of electricity that motor M**1** draws from power supply **110**, based on signal **114** from sensor **112**. For example, control unit **16** may include a controller **116** and a modulating device **118** in communication with the controller **116**. As shown, modulating device **118** may be positioned such that it is in electrical communication with power supply **110** for motor M**1**. As described in further detail below, modulating device **118** may be adapted to restrict the amount of electricity that motor M**1** draws from power supply **110**, based on a command **120** by controller **116**.

As also illustrated in FIG. **13**, power supply **110** may include an electrical connector **122**, through which electricity may travel from power supply device **124** to ground **126**, via supply wires **128***a*, **128***b*, **130**, and motor M**1**. Electrical connector **122** thus allows motor M**1** to receive electricity from power supply **110**, i.e., via supply wire **130**, which provides electrical communication between motor M**1** and connector **122**. In this manner, motor M**1** can be 'plugged into' control system **108**, to receive a desired amount of power therefrom, as will now be explained.

Controller **116** may be adapted, e.g., programmed, to cause modulating device **118** to impose a restriction on the amount of electricity that motor M**1** draws from power supply **110** when the signal **114** from sensor **112** has a value that is greater than or equal to the predetermined value, e.g., a value that corresponds to the 'jamming point' for the paper sheets **18**. Controller **116** may also be adapted, e.g., programmed, to remove the restriction when the signal **114** from sensor **112** has a value that is less than the predetermined value. The predetermined sensor value corresponding to the 'jamming point,' once determined empirically, i.e., through routine experimentation at a number of different density settings, can be programmed into the controller **116**. As is conventional, e.g., when controller **116** is a microcontroller, a PLC, a PAC, etc., the predetermined input value from sensor **112** corresponding to the jamming point can be programmed into the controller during initial programming as part of the written source code; this value may be changed as desired by an ordinarily-skilled technician, e.g., via an interface device that may be connected directly or indirectly to controller **116**. As is also conventional, controller **116** may be part of a printed circuit board (PCB), which may include some or all of the components illustrated in FIG. **13**. For example, the control system **108** may be in the form of a PCB, e.g., as a sub-assembly within a larger PCB, which controls/monitors all or most of the components of machine **10** or **10'**.

As illustrated in FIG. **13**, sensor **112** may include a current-sensing resistor **132** in electrical communication with power supply **110**, and a signal-generating device **134**, which generates signal **114** based upon the current sensed by resistor **132**, i.e., in power supply **110**. The signal-generating device **132** may include an integrated circuit and additional devices, e.g. resistors and capacitors, as necessary to generate signal **114**, which may be in the form of a an electric current and read by controller **116** as amperage or voltage. As an example, when power supply device generates 24 volts of direct current

(DC), and motor M1 is a DC motor that can draw current ranging from 0 to 5 amperes (A), the signal-generating device **134** may be calibrated such that the signal **114** generated by the device **134** ranges from 0-1.62 volts (V), with 0 (zero) V corresponding to 0 (zero) A drawn by motor M1, and 1.62 V corresponding to 5 A drawn by motor M1. If it is determined, e.g., empirically, that a current draw of 2.3 A by motor M1 is the 'jamming point,' i.e., indicates that the overlap **26** being formed between successive sheets **18** is such that paper jamming is imminent or probable, and this corresponds to a signal value **114** of 0.75 V, then 0.75 V can be programmed into controller **116** as the predetermined value at which to impose a restriction on the amount of electricity that motor M1 can draw from power supply **110**.

In some embodiments, modulating device **118** may be adapted to restrict the amount of electricity that motor M1 can draw from power supply **110** by simply reducing the amount of current that can flow through the device **118**, i.e., upon command by controller **116**. When device **118** is arranged in series with power supply **110** with connector **122** as shown, this will effectively reduce the amount of current that motor M1 can draw. Modulating device **118** may function in this manner when embodied, e.g., as an adjustable power supply device, such as an adjustable DC/DC converter. With such embodiment, modulating device **118** and power supply device **124** could be combined into a single device and positioned, e.g., where power supply device **124** is located in FIG. **13**.

In other embodiments, modulating device **118** may be adapted to restrict the amount of electricity that motor M1 can draw from power supply **110** by 1) imposing upper and lower limits on the amount of electricity that motor M1 draws from power supply **110**, based on a command by controller **116**, and then 2) oscillating between the upper and lower limits at predetermined intervals, as also commanded by controller **116**. In this manner, the current supplied to motor M1 pulses between the upper and lower limits, which causes the force exerted by motor M1 on sheets **18** to also pulse, thereby reducing the tendency for the sheets to become misaligned and jam. In order to perform this function, modulating device **118** may be embodied by a switching device, such as a field-effect transistor (FET), a bipolar junction transistor (BJT), or other electrical device that can switch at a desired frequency and withstand the voltage/current requirements of motor M1.

Accordingly, by measuring the amount of electricity drawn by motor M1, comparing this to a predetermined value indicative of the onset of the 'jamming point,' and then modulating the amount of electricity that motor M1 can draw once the jamming point is reached, a desired degree of overlap **26**, leading to a desired packaging-cushion density, can still be achieved, but with a reduced likelihood of sheet misalignment and jamming.

EXAMPLE

With reference to FIGS. **7** and **13**, machine **10'** was constructed and sized to convert sheets **18**, which comprised paper having a width of 17 inches and a length of 20 inches, into packaging cushions **106**. The machine included a control system **108** with the following components:

1) Motor M1 was a DC Brush-Gearmotor, GM 9000 Series from Pittman Corp., with a 5.9:1 ratio and 48 oz-in continuous torque.

2) Power supply device **124** was an AC/DC converter that converts AC voltage to 24 volts DC; the device was a model SP-320-24 Switching Power Supply from Meanwell Corp., Universal AC Input (88 to 264V AC), 50/60 Hz, which converts AC voltage to 24 VDC @ 13 A.

3) Modulating device **118** included a FET and a FET driver, wherein the FET driver received commands from the controller **116** and actuated the switching action of the FET. The FET was a model IRLZ44ZPBF from International Rectifier Corp., with the following characteristics: N-channel, TO-220, logic level, Vdss=55V. The FET driver was a model MCP1407-E/SN from Microchip Corp., with the following characteristics: IC (integrated circuit), 6A, 8-SOIC, non-inverting.

4) Controller **116** was a model MC9S12A256CPVE microcontroller from Freescale Corp., which was an IC-type MCU, 256K flash, 16 bit device.

5) Sensor **112** included a model MAX4172EUA+ type IC from Maxim Corp., with an amplifier and 8-Umax package, as the signal-generating device **134**. The current-sensing resistor **132** was a model MSR-5 resistor from Riedon Corp., with the following characteristics: 0.01 ohm, 5W 1% bare element. A resistor and capacitor were situated in parallel to ground to receive the output from signal-generating device **134**, which converted signal **114** to one ranging from 0 to 1.62 volts.

Machine **10'** was operated at a number of different conditions to produce a range of densities for the resultant packaging cushions **106**, until it was determined that a motor M1 draw of 2.3 A was the jamming point, i.e., indicted the imminent or probable onset of a paper jam by sheets **18**. The value of signal **114** from sensor **112** corresponding to a motor draw of 2.3 A was 0.75 volts, and this was programmed into controller **116** as the predetermined value at which to initiate modulation of the amount of electricity that motor M1 thereafter draws.

During all periods when sensor **112** detected that motor M1 was drawing less than 2.3 A, controller **116** sent a command **120** to modulating device **118**, which resulted in the operation of the modulating device such that motor M1 was allowed to draw 24 V of electricity from power supply **110** in a pulsed fashion at 50-microsecond intervals, with full power (24 V) for 32.5 microseconds (65% of each interval) and zero power (0 V) for 17.5 microseconds (35% of each interval). This was a 'normal duty' pulse rate.

When sensor **112** detected that motor M1 was drawing 2.3 A or more, controller **116** altered command **120** such that modulating device **118** imposed a restriction on the amount of electricity drawn by the motor. This was accomplished by cycling, every 10 milliseconds, between the 'normal duty' pulse rate as described immediately above, and a 'low duty' pulse rate, in which modulating device **118** allowed motor M1 to draw full power for 20 microseconds (40% of each 50 microsecond interval) and zero power for 30 microseconds (60% of each interval). This restriction, i.e., cycling every 10 milliseconds between the normal and low duty pulse rates, continued until the detected draw rate of motor M1 fell below 2.3 A, at which point modulating device **118** reverted to the 'normal duty' pulse rate for motor M1, by way of command **120** from controller **116**.

When operated in the foregoing manner, machine **10'** was able to produce packaging cushions **106** of various densities while avoiding about 95% of all paper jams that would otherwise have been caused by overlaps **26**.

The foregoing description of preferred embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention.

What is claimed is:

1. A machine for producing packaging cushioning, comprising:

a. a first feed mechanism for successively feeding sheets of a substrate at a first speed, said first feed mechanism including a motor and a power supply therefor, wherein said motor is capable of drawing a varying amount of electricity from said power supply when said first feed mechanism feeds said sheets;

b. a second feed mechanism for receiving said sheets from said first feed mechanism and feeding said sheets at a second speed;

c. a control unit for controlling at least one of said first and second speeds to produce a desired degree of overlap between successive sheets; and

d. a sensor to measure the amount of electricity drawn by said motor, said sensor being structured and arranged to generate a signal, which is indicative of the amount of electricity drawn by said motor, and communicate said signal to said control unit,

wherein, said control unit is structured and arranged to modulate the amount of electricity that said motor draws from said power supply when said signal from said sensor has a value that is greater than or equal to a predetermined value.

2. The machine of claim **1**, wherein said second feed mechanism is a crumpling mechanism, which converts said sheets into packaging cushion units.

3. The machine of claim **2**, wherein

said machine is configured to connect the packaging cushion units together in series, and

the connected series of packaging cushion units has a density that is proportional to said degree of overlap between successive sheets.

4. The machine of claim **3**, wherein said crumpling mechanism comprises a pair of compression members that connect said packaging cushion units together by crumpling the sheets at said overlap between successive sheets.

5. The machine of claim **3**, wherein:

said sheets have a length dimension and a width dimension; and

said machine further includes a convergence device, at least part of which is positioned between said feed mechanism and said crumpling mechanism for reducing the width dimension of the sheets.

6. The machine of claim **5**, wherein:

said sheets have a pair of opposed lateral sides;

said convergence device causes said lateral sides to converge towards one another; and

said crumpling mechanism crimps said converged lateral sides.

7. The machine of claim **6**, wherein:

each packaging cushion unit comprises a pair of end regions bounding a central region;

said end regions correspond to said overlap between successive sheets;

said convergence device causes said lateral sides to converge towards one another within said end regions; and

said crumpling mechanism crimps the end regions of adjacent cushion units together, thereby connecting said packaging cushion units together.

8. The machine of claim **2**, wherein said crumpling mechanism comprises a pair of compression members that convert the sheets into packaging cushion units by compressing the sheets therebetween.

9. The machine of claim **1**, wherein:

said first speed is greater than said second speed; and

said degree of overlap between any two successive sheets ranges from greater than 0% to less than 100%.

10. The machine of claim **1**, wherein said packaging cushion units are connected such that each packaging cushion unit is slidingly separable from an adjacent packaging cushion unit.

11. The machine of claim **1**, wherein said packaging cushion units are connected together via a friction fit, which is produced by said crumpling of said sheets at said overlap between successive sheets.

12. The machine of claim **1**, wherein:

said control unit includes a controller and a modulating device in communication with said controller; and

said modulating device is in electrical communication with said power supply for said motor, and is adapted to restrict the amount of electricity that said motor draws from said power supply, based on a command by said controller.

13. The machine of claim **12**, wherein said modulating device is further adapted to:

impose upper and lower limits on the amount of electricity that said motor draws from said power supply, based on a command by said controller; and

oscillate between said upper and lower limits at predetermined intervals as commanded by said controller.

14. The machine of claim **12**, wherein said controller is adapted to cause said modulating device to:

impose said restriction on the amount of electricity that said motor draws from said power supply when said signal from said sensor has a value that is greater than or equal to said predetermined value; and

remove said restriction when said signal from said sensor has a value that is less than said predetermined value.

15. The machine of claim **1**, wherein said sensor comprises:

a current-sensing resistor in electrical communication with said power supply; and

a signal-generating device, which generates said signal based upon the current sensed by said resistor.

* * * * *